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Keynotes

ID: 1 / Presentation: 1
Keynote Thursday, July 12th

MoBI for investigating disordered motor control in children with cerebral palsy

Diane Damiano[1]

[1]National Institute of Health, Bethesda, USA

Abstract: Early brain injury, as seen in cerebral palsy (CP), transforms the nervous system and motor development in often very individualized and unpredictable ways. While static structural images of grey and white matter can document differences between children with and without CP and relate location and severity of abnormalities to functional abilities, these provide little insight into brain activation during everyday motor tasks in an individual child. MoBI techniques, such as EEG and fNIRS, hold great potential for uncovering the neural mechanisms underlying motor development and coordination and how these may be disrupted in CP with the ultimate goal to design more effective biologically based and personalized motor training paradigms. We will discuss some of our initial results in age-matched cohorts with and without CP during a range of upper and lower extremity motor tasks from squeezing a ball to walking using NIRS or EEG with a primary focus on relating cortical activation to muscle activation. Intriguing differences in the maturation of the sensorimotor system across groups are also emerging. We will briefly discuss how MoBI in pathological conditions also conveys novel challenges for the field due to distorted anatomy and behavioral limitations as well as the growing interest in applying these techniques in combination, in very young infants, and as outcome measures in clinical trials.

ID: 2 / Presentation: 2
Keynote Thursday, July 13th

Exercise your Brain and Mind

Art Kramer[1]

[1]Northeastern University, Boston, USA

Abstract: The presentation will focus on recent research that has examined the effects of exercise training interventions on cognitive and brain health. I will discuss research that has examined changes in brain structure and/or function along with behavioral measures of cognition in interventions lasting from several weeks to 1 year. Study populations will include children, young and middle-aged individuals, and the elderly in addition to a variety of patient groups. Although the focus will be on training to improve cardiorespiratory fitness I will also briefly cover resistance training and well as multi-modal cognitive and exercise training program. Finally, the presentation will identify gaps in the literature and potential solutions.

ID: 3 / Presentation: 3
European Journal of Neuroscience Keynote Friday, July 14th

EJN Keynote: Mobile Brain/Body Imaging – Past, Present, Future

Scott Makeig[1]

[1]University of California San Diego, San Diego, USA

Abstract: This talk will provide an overview of Mobile Brain/Body Imaging, its origins, state of the art and future.

Invited Oral Presentations

ID: 01 / Presentation: 1
Invited Oral Presentation
Session: MoBI Hardware and Software

Simulink brain signal interface (SimBSI): An open-source graphical environment for the rapid development of animal and human BCI

Alejandro Ojeda[1]

[1]University of California San Diego, San Diego, USA

Abstract: An important goal of clinical neuroscience is to move towards personalized therapies that can target specific neural circuit dysfunctions that lead to neuropsychiatric disorders. To accomplish this goal, it is necessary to understand brain function across multiple scales, from single neurons to large-scale brain networks, and their dynamic interaction with the environment, hence, requiring neurophysiological investigations across animals (single-cell and local-field-potential recordings) and humans (whole-brain recordings). To address these needs we have developed Simulink brain signal interface (SimBSI), an open-source graphical environment for the rapid prototyping of animal and human brain-computer interfaces (BCIs). SimBSI is designed as a library on top of the graphical programming environment of Simulink (MATLAB), with three goals in mind. 1) To provide a flexible cognitive platform for developing human and animal experiments by using Simulink's Stateflow programming. 2) To allow for flexible data acquisition by including multiplatform drivers for standard instrument communication protocols (including the Lab Streaming Layer). 3) To allow for real-time analysis and control of neural circuit dynamics by leveraging Simulink's DSP and Control toolboxes in addition to a customized neuroimaging module. With this library, we hope to ease the development of individualized BCI-based therapies while contributing a tool for deepening our understanding of the neurobiological and environmental basis of neuropsychiatric disorders.

ID: 02 / Presentation: 2
Invited Oral Presentation
Session: MoBI Hardware and Software

Brain Computer Interface (BCI) for Driving Cognition

Chin-Teng Lin[1]

[1]University of Technology Sydney, Sydney, Australia

Abstract: In the simplest terms, the Brain-Computer Interface (or BCI) allows the brain to collaborate with a device and interact directly with the environment. BCI is widely considered a 'disruptive technology' for the next-generation human-computer interface in wearable computers and devices. In particular, there are incredible potential real-life applications of BCI in augmenting human performance for people in health and aged care. Despite this, there are limitations. Human cognitive functions, such as action planning, intention, preference, perception, attention, situational awareness, and decision-making, although omnipresent in our daily lives, are complex and hard to emulate. Yet, by studying the brain and behavior at work, a BCI plays an incredibly important role in natural cognition. Discover the latest thinking in the realm of the Brain-Computer Interface in this lecture. Listen the current status of BCI and discusses its three major obstacles: the shortage of *wearable* EEG devices, the various forms of noise contamination that hinder BCI performance, and the lack of suitable adaptive cognitive modeling. This talk will introduce the fundamental physiological changes of human cognitive functions at driving and explain how to combine the bio-findings and AI techniques to develop monitoring and feedback systems enhance driving safety.

ID: 03 / Presentation: 3
Invited Oral Presentation
Session: MoBI Hardware and Software

Neuroimaging in the real-world with novel wearable and mobile fNIRS devices

Paola Pinti[1]

[1]University College London, London, United Kingdom

Abstract: The assessment of functional brain activity in everyday life situations represents the new frontier for cognitive neuroscience investigations. This becomes particularly important to investigate prefrontal cortex (PFC) function and dysfunction that cannot be properly studied in typical laboratory settings. In fact, the physically restrained and artificial environments such as a fMRI scanner can influence our behavior and reduce the ecological validity of our measurements. This can lead to a disagreement between measurements taken in the lab and in real-life, especially in case PFC lesions. Thanks to the recent technological advancements, we have now new mobile and wearable functional Near Infrared Spectroscopy (fNIRS) devices that allow imaging functional brain activity in more ecologically-valid situations such as outside the lab and on freely-moving people. However, the use of fNIRS in more naturalistic contexts presents several challenges, including the design of appropriate functional activation protocols, the technology limitations, the localization and inference of functional brain activity, and the impact of systemic physiological changes. In addition, in case of unstructured cognitive tasks, the identification of functional events in real-world experiments can be inaccurate. In this talk, I will present a feasibility study on the use of fNIRS to monitor PFC hemodynamics and oxygenation on people freely-moving outside the lab while undertaking an ecological cognitive task investigating executive functioning. In particular, the issues associated with real-world neuroimaging and possible solutions to overcome them will be discussed, and a novel algorithm for the identification of functional events in unstructured cognitive experiment will be presented.

ID: 04 / **Presentation: 4**
Invited Oral Presentation
Session: MoBI Hardware and Software

Developing a Multi-modal Bio-Sensing and Activity Tagging Platform for MoBI Research

Tzyy-Ping Jung[1]

[1]University of California San Diego, San Diego, USA

Abstract: Research in multi-modal bio-sensing has traditionally been restricted to well-controlled laboratory environments. Such bio-sensing modalities used to measure electroencephalogram (EEG), electrocardiogram (ECG), pupillometry, eye-gaze and galvanic skin response (GSR) are typically bulky, require numerous connections, costly, hard to synchronize, and have low-resolution and poor sampling rates. Thus, they are not practical for routine use by unconstrained users in real-world environments. Furthermore, they lack a method to automatically tag cognitively meaningful events. Developing a research-grade wearable multi-modal bio-sensing system would allow us to study a wide range of previously unexplored research problems in real-world settings. We present a novel multi-modal bio-sensing platform capable of integrating, synchronizing and recording multiple data streams for use in real-time applications. The system is composed of a central compute module and a companion headset. The compute node collects, time-stamps and transmits the data while providing an interface for a wide range of sensors including EEG, ECG, GSR, photoplethysmgram (PPG), full-body motion capture, and eye gaze among others. Though some of the integrated sensors are designed from the ground-up to fit into a compact form factor, we validate the accuracy of the sensors and find that they perform similarly to, and in some cases better than, alternatives. By providing a wearable platform that is capable of measuring numerous modalities in the real world and that has been benchmarked against state-of-the-art tools, we hope to expand the deplorable questions in MoBI research.

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Invited Oral Presentation
Session: MoBI Hardware and Software

Developing portable, mobile, and transparent EEG

Stefan Debener[1]

[1]University of Oldenburg, Oldenburg, Germany

Abstract: Most technologies for the non-invasive recording of human brain activity do not tolerate motion during signal acquisition very well. This poses an obvious dilemma to the field of behavioural brain sciences. Unfortunately, recently developed mobile EEG systems, while portable, are not necessarily mobile, that is, they do not feature motion-robust signal acquisition. Another problem is that these systems are clearly visible and therefore cannot be used in daily-life situations. A transparent EEG, on the other hand, would not only be portable and motion-tolerant, it would also feature low visibility and generally minimal interference with daily-life activities. The recording of brain-electrical activity from the outer ear and around the ear may be an important step towards reaching this ambitious goal. I will summarize our work on developing mobile and transparent EEG technology, with a strong focus on reporting the limitations and possibilities of smartphone EEG acquisition. Examples will include ear-EEG acquisition with flex-printed cEEGrid sensors, sleep-EEG, and the subsequent memory effect captured on smartphone.

ID: 06 / **Presentation: 6**
Invited Oral Presentation
Session: MoBI Hardware and Software

A Python-based Software Platform for Multi-Modal Signal Processing and BCI

Tim Mullen[1]

[1]Intheon, San Diego, USA

Abstract: In this talk we will present and demonstrate the NeuroPype Suite Academic Edition, a suite of desktop applications made available for free to the scientific community with the goal of accelerating and streamlining the creation, deployment, and sharing of pipelines for real-time or batch processing and decoding of unimodal and multi-modal sensor data (e.g. EEG, ExG, intracranial electrophysiology, actigraphy, eye tracking, audio and video signals, etc). The suite includes a version of NeuroPype, an extensible Python-based dataflow programming environment, containing 250+ modular data processing and visualization routines ("nodes") that can be configured and linked together to create and run pipelines for signal processing and analysis, BCI and signal classification, neuroimaging, closed-loop feedback and control, and more. NeuroPype integrates seamlessly with the open-source Lab Streaming Layer (LSL) protocol for data acquisition, synchronization, and I/O, and works out of the box with LSL-compatible hardware devices. An extensible framework enables users to add their own custom processing nodes in Python, while a RESTful API allows external applications to interface with NeuroPype to create, run and configure pipelines in real-time. While NeuroPype can be operated entirely programmatically, the suite also includes Pipeline Designer, an open-source visual programming application based on Orange which provides an intuitive drag-and-drop GUI for pipeline design and configuration through NeuroPype's API. We will illustrate both local deployment of NeuroPype pipelines, as well as deployment on the NeuroScale cloud platform for streaming access to/from mobile and other internet-connected devices and for scalable batch processing.

ID: 07 / Presentation: 7
Invited Oral Presentation
Session: Cognition and Motor Function

What can humanoid robots tell us about mechanisms of human cognition?

Agnieszka Wykoswka[1]

[1] Istituto Italiano di Tecnologia, Genua, Italy

Abstract: In my lab, we investigate the mechanisms of human social cognition with the use of naturalistic interactive protocols including embodied artificial agents (humanoid robots) and cognitive neuroscience methods. Experimental protocols with humanoid robots allow for more ecological validity than standard screen-based stimuli, thanks to the embodied presence of the robot. At the same time, they also allow excellent experimental control. We are interested in the behavioural characteristics of the robot that evoke the mechanisms of social cognition (such as joint attention, action prediction). In this talk, I will present a collection of studies that examined how joint attention was influenced by factors such as:

- real-time mutual gaze and gaze avoidance,
- contingency of the robot’s gaze behavior,
- expectations regarding action sequences.

These studies have been conducted with the use of the humanoid robot iCub, designed at our Institute (IIT). We integrate iCub in interactive protocols in which we measure – during interaction– participants’ EEG, gaze behavior (with a wireless mobile eyetracker) and performance. Our results show that embodied presence of an agent casts a new light on social cognitive mechanisms. For example, gaze cueing effects (behavioural and EEG) are modulated by whether the robot engages participants in mutual gaze or avoids gaze (prior to the gaze cueing procedure). We propose that through the use of artificial agents and realistic interactive protocols, we can learn how human (social) cognition works in real life.

ID: 08 / **Presentation: 8**

Invited Oral Presentation
Session: Cognition and Motor Function

Ecological Validity of the N170 – a mobile EEG study

Peter Koenig[1]

[1]University of Osnabrück, Osnabrück, Germany

Abstract: Are event related potentials, well investigated under laboratory conditions, a signature of cortical processing during natural behavior? We explore this question with a fully mobile recording setup. It integrates and synchronizes an EEG system, a mobile eye tracker with pupil- and world-cameras, as well as a step-sensor. These data are compared to recordings with more restricted behavior as well as classic fully controlled laboratory conditions. With a focus on the N170 ERP we streamline the data analysis using deep neural networks to categorize elements like faces in the participant's surrounding. We find that widely reported effects are not as robust as they seemed. However, free viewing of static images and passive presentation leads to comparable results. Finally we present data on the step-wise bridge the gap between lab and real world recordings.

ID: 09 / Presentation: 9
Invited Oral Presentation
Session: Cognition and Motor Function

Neural markers of attentional processing in dynamic real-world environments

Simon Ladouce1, David I. Donaldson, Paul Dudchenko, & Magdalena Ietswaart
[1]University of Stirling, Stirling, Scotland

Abstract: Current knowledge about the neural correlates of attentional processing comes largely from lab-based research. As a result, little is known about how these processes respond in the face of complex environments. In this talk, a series of experiments using mobile EEG to examine attentional processing in the real-world will be presented. We used a neural marker of attention, the Event Related Potential (ERP) P300 effect. In Experiment 1 we found that attention allocated to the detection of infrequent target stimuli is reduced when human participants walk down a familiar hallway compared to when they stand still. Experiment 2 extended this finding by demonstrating that this reduction in the neural marker of attention is not caused by the act of walking per se, but rather is associated with movement through the environment. Experiment 3 identified the independent processing demands driving reduced attention to target stimuli. Taken together, these findings demonstrate the potential of a real-world approach to brain imaging, to reveal detectable reductions in attentional processing when participants are engaged in real-world behaviour.

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Invited Oral Presentation
Session: Cognition and Motor Function

Age-related differences in brain dynamics of visual perception during walking

Janna Protzak[1]

[1]Berlin Institute of Technology

Abstract: Human activities are rarely restricted to isolated tasks and consequently linked to several cognitive and perceptual processes. Especially in older adults, effective resource allocation in parallel processing is crucial as aging is often associated with interdependent compensation mechanisms due to age-related cognitive and sensory declines. Everyday tasks like the maintenance of a stable and secure gait can require increased cognitive control leaving fewer resources for concurrent tasks such as scanning the traffic for approaching cars or the environment for obstacles. Although techniques to record neurophysiological data during realistic locomotion are nowadays possible using Mobile Brain-Body Imaging (MoBI) approaches, the interdependencies of visual perception and motor performance and the underlying brain dynamics are not yet understood in detail. In this talk, I will present results from two dual-talk studies investigating peripheral visual perception and motor task performance in older and younger adults. Age-related differences in performance, gait and posture data as well as neurophysiological measures and their interdependencies with different levels of motor-activity (sitting, standing, walking) will be discussed. In addition, experiences and benefits of MoBI-research with older adults will be outlined.

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Invited Oral Presentation
Session: Cognition and Motor Function

Mobile Brain-Body Imaging to develop neuromarkers of age-related cognitive disorders

John Foxe[1]

[1]University of Rochester Medical Center, Rochester, USA

Abstract: The use of high-density electrophysiological recordings in individuals while they are ambulating makes it clear that the neural circuitry of cognitive control is differentially engaged as a function of active mobility. That cognitive operations require reconfigurations of control circuitry during activity raises the possibility that such reconfigurations may not be properly engaged in unhealthy aging; that is, those who are beginning to develop the prodromal phases of cognitive impairment, Alzheimer's Disease or related dementias. In a series of studies, we have established clearly differential neural processing in elderly individuals as a function of gait parameters and environmental sensory challenges. We will discuss these results and the potential utility of MOBI in establishing endophenotypes of aging-related cognitive decline.

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Invited Oral Presentation
Session: Cognition and Motor Function

Embodied brain dynamics of spatial cognition

Klaus Gramann[1,2,3]

[1]Berlin Institute of Technology, Berlin, Germany;
[2]School of Software, University of Technology Sydney, Sydney, Australia;
[3]Center for Advanced Neurological Engineering, University of California, San Diego, CA, USA;

Abstract: Established brain imaging approaches to investigate spatial cognitive processes require stationary setups and immobile participants. During natural spatial orientation, however, humans make use of idiothetic information originating from movements and contributing to spatial updating. Here I present a Mobile Brain/Body Imaging (MoBI, Makeig et al., 2009; Gramann et al., 2011) method to investigate natural spatial cognitive processes including heading computation and learning of new environments. With a focus on the retrosplenial complex (RSC) and its role in heading computation, I present different studies demonstrating differences in RSC activity during spatial orienting based on physical movement as compared to visual flow only. During rotations, the data indicate velocity dependent frequency modulations during physical but not visual flow rotations in the beta frequency range in the RSC and increased activity in a wide frequency range in bilateral inferior parietal cortices. During learning of spatial mazes, the RSC demonstrates pronounced and earlier onset activity for well-known mazes as compared to unknown mazes in the alpha and beta frequency bands. These results indicate that the brain dynamics in RSC during physical movement in space differ markedly from visual flow movement even with identical visual input.

ID: 13 / Presentation: 13
Invited Oral Presentation
Session: Gait and gait Rehabilitation

Reliable ICA and synchronization of brain and muscle activity for MoBI paradigms

Fiorenzo Artoni[1]

[1]École Polytechnique Federale de Lausanne, Lausanne, Switzerland

Abstract: Mobile Brain/Body Imaging (MoBI) is rapidly gaining traction as a new imaging modality to study how cognitive processes support movement in the real world. Issues associated to synchronization of multiple streams and the presence of artifacts (e.g., cable movement, electrode-gel coupling, EMG, blinks, saccades, eye bounce etc.) however often restrict the availability of the MoBI paradigm to high-end research facilities. Regarding multi-stream data synchronization, we tested the effectiveness of a fallback strategy (spikes alignment at the beginning and ending of a recording), which enables to achieve MoBI-grade synchronization of EEG and EMG, when other strategies such as Lab Streaming Layer (LSL) cannot be used, e.g., due to the unavailability of proprietary Application Programming Interfaces (APIs), as it is often the case in clinical settings. We show that synchronization cannot rely only on the equipment sampling rate advertised by manufacturers: repeated spike delivery can be used to test online synchronization options and to troubleshoot synchronization issues over EEG and EMG. The talk will also cover advancements on the integration of Reliable Independent Component Analysis (RELICA) to MoBI preprocessing pipelines. RELICA helps enhancing the removal of artifacts and reliably disentangling information from noise, thus ensuring that components retained for further analyses are both stable (i.e., not a result of algorithm instability, noise or mechanical artifacts) and dipolar (i.e., fitted by an equivalent dipole with low residual variance).

ID: 14 / Presentation: 14
Invited Oral Presentation
Session: Gait and gait Rehabilitation

Mobile Brain/Body Imaging of Dual-Task Walking in Aging

Pierfillipo de Sanctis[1]

[1]Albert Einstein College New York, New York, USA

Abstract: Mobility stress tests such as dual-task walking are particularly suited to unmask subtle gait changes in adults aged 65 and older. This is important, as quantitative gait markers are independent predictors of negative outcomes such as falls and cognitive decline. Further, structural neuroimaging highlights cortical contributions by linking gait variability in aging to atrophy in medial areas important for lower limb coordination and balance. Advancing our knowledge of the electro-cortical underpinnings of such complex cognitive-motor behavior will provide relevant clinical insight. Hence, our goal is to further EEG-based Mobile Brain/Body Imaging (MoBI) as a clinical research tool to determine changes in cognitive, sensory, and motor coupling with advanced age and neurological disorders such as multiple sclerosis. We employ a 3D infra-red camera system to monitor gait and posture during ambulation while high-density electrophysiology is simultaneously recorded. We vary sensory load by manipulating full-field optical flow stimulation as well as task-load, as participants will also perform cognitive tasks while walking in this environment. I will provide an overview of our work addressing the test/retest reliability of EEG signals while walking, the use of event-related potentials to map age differences, and power spectral density of localized ICA sources to assess cortical network activity during dual-task walking. In addition, I will present ongoing efforts to determine electro-cortical signals associated with increased gait variability in aging. We believe MoBI will provide new insights to enhance the mobility and quality of life of older individuals.

ID: 15 / Presentation: 15
Invited Oral Presentation
Session: Gait and gait Rehabilitation

EEG correlates of perturbation-driven adaptation in recumbent stepping

Helen Huang[1]

[1]University of Central Florida, Florida, USA

Abstract: Understanding the electrocortical dynamics of locomotor tasks such as recumbent stepping and cycling can provide insight for prescribing gait rehabilitation therapies when gait rehabilitation involving walking is not practical. The use of perturbations during locomotor tasks such as cycling and recumbent stepping has only recently begun to be explored as another approach for promoting locomotor adaptation. As such, there is a need to understand the underlying electrocortical dynamics driving locomotor adaptation during walking and other locomotor tasks. The purpose of this study was to determine the electrocortical correlates of adapting to mechanical perturbations on a robotic recumbent stepper. Electroencephalography (EEG) was recorded as healthy young adults performed recumbent stepping with 4 types of perturbations, which were brief increases in resistance at step initiation and mid-step of each leg. For each perturbation type, the protocol was 2 minutes of unperturbed stepping (baseline), 6 minutes of perturbed stepping, and ending with 2 minutes of unperturbed stepping. Perturbations were applied during each stride except 1 out of every 5 strides was a “catch” trial where no perturbation was applied. After stepping for just 6 minutes with one type of perturbation, stepping patterns shifted away from the baseline to a new sustained stepping pattern. By the end of perturbed stepping, sources in the anterior cingulate showed increased theta (4-7 Hz) band synchronization that corresponded with the timing of the perturbation. These results suggest that increased anterior cingulate theta synchronization may underlie perturbation-driven adaptation during recumbent stepping towards new sustained stepping patterns.

ID: 16 / Presentation: 16
Invited Oral Presentation
Session: Gait and gait Rehabilitation

Gait-related cortical dynamics from the EEG source imaging perspective

Martin Seeber1

[1]University of Geneva, Geneva, Switzerland

Abstract: Intact gait function is a prerequisite to ensure mobility and independence for people. Cortical contributions to lower limb function are relevant, since brain injuries and impairment of the corticospinal tract can cause motor disabilities. Nonetheless, we are just only beginning to understand the involvement of cortical dynamics in generation and control of gait. I will describe the use of electroencephalographic (EEG) source imaging techniques to reconstruct and study cortical dynamics during gait in humans. In particular, I will show that the combination of EEG source imaging, advanced computational techniques for artefact suppression, and motion tracking is necessary to enable mobile brain imaging (MoBI) during gait. We used these MoBI techniques to study the modulation of cortical oscillations in healthy volunteers as they walked on a treadmill supported by a robotic gait orthosis. We distinguished state transitions between standing and walking from dynamic modulations within the gait cycle. Both of these perturbations were focally located in central sensorimotor regions, i.e. in accordance with leg motor cortical areas. Interestingly, sustained- and gait-phase related activities were associated with two distinct frequency-specific networks. First, movement-state related networks, which upregulate cortical excitability in sensorimotor leg areas. Second, gait-phase related networks, which modulate their frequency-specific synchrony in relation to the gait cycle. In ongoing and future work, we aim to use these two types of gait-related cortical dynamics for real-time decoding of gait events in healthy volunteers and people with spinal cord injury. Our ultimate goal is to develop a therapeutic system where decoded gait events trigger spinal cord stimulation protocols to support gait rehabilitation after spinal cord injury.

ID: 17 / Presentation: 17
Invited Oral Presentation
Session: Gait and gait Rehabilitation

Wearable technology for enhanced insight during mobile neuroimaging

Julia Kline1

[1]Fitbit, San Francisco, USA

Abstract: Wearable technology is a rapidly expanding field with great untapped potential for mobile human experiments. Small, non-invasive sensors record biomechanical and physiological signals in real-time as subjects move freely. Combining wearables with traditional neuroimaging methods provides novel insight into brain-body dynamics. Furthermore, wearable technology is itself beginning to move into the area of direct brain monitoring and neuromodulation. In just one segment of the wearables market, fitness bands, dozens of novel sensors have emerged that provide complementary data for neuroimaging experiments. Heart rate and respiratory rate is computed with photoplethysmograph. Galvanic skin response provides insight into minute-to-minute emotional valence. Accelerometry allows for the reconstruction of gait patterns or even the classification of movement type during mobile experiments, to name just a few applications. Furthermore, wearables themselves are beginning to tap into or modulate brain signals. Today, commercial wearables utilize electroencephalography (EEG) and transcranial magnetic stimulation (TMS). While these technologies are in their early stages, they may one day provide a lower cost alternative to traditional neuroimaging. With all this potential for insight, wearables are increasingly being incorporated into big data initiatives. This talk will examine the state-of-the-art of wearable sensing for mobile neuroimaging applications. It will provide examples of how novel sensors have been used to gain insight into brain-body dynamics and to tackle big data questions in neuroscience.

ID: 18 / Presentation: 18
Invited Oral Presentation
Session: Gait and gait Rehabilitation

Removing Motion Artifact from EEG for Mobile Brain Imaging

Dan Ferris1

[1]University of Florida, Florida, USA

Abstract: A common problem with mobile EEG is motion artifact. As humans walk and run, they induce increases and decreases in EEG spectral power across a range of frequency bands. We have created a novel noise-cancelling dual layer EEG system that devotes one electrode to pure motion artifact recording and a second electrode to a mix of biological signal and motion artifact recording. Using either time-series or spectral frequency subtraction, it is possible to reproduce a much higher fidelity representation of the true electrocortical signals. I will describe the dual-layer EEG system and discuss how we validated the system with an electrical head phantom and robotic motion platform. The approach is feasible for a wide range of EEG electrodes and could greatly improve the ability to study human brain dynamics in active real-world tasks.

ID: 19 / **Presentation: 19**
Invited Oral Presentation
Session: Neuroarchitecture, Performing Arts & Dance

Automatic MoBI feature extraction and visualization in visual art production

Jesus G. Cruz-Garza, Girija Chatufale, **Jose Luis Contreras-Vidal[1]**

[1]University of Houston, Houston, USA

Abstract: Human creativity was explored in the context of the exquisite corpse protocol – a collaborative, chance-based game made famous by the Surrealists in the 1920s. The players attempt to create a “body” consisting of a head, torso, and legs – 15 minutes for each segment. Three visual artists worked together, by observing the edge of the previous composition to begin their own. Artists were instrumented with wireless 62-channel EEG, inertial measurement units, and video cameras in a public setting. A classical machine learning approach using kSVM was compared to a deep learning approach using convolutional neural networks (CNN). The kSVM input were time and frequency-domain features in 1s windows with 50% overlap. The CNN took the EEG time windows of 62 channels as input. A four-class classification problem yielded over 79% accuracy across subjects, with similar performance in the kSVM and CNN methods. The most relevant EEG features were found in frontal (1-4 Hz, 8-12 Hz), central (8-12 Hz, 30-50 Hz), and posterior (8-50 Hz) brain networks, consistent both in the predefined set of features and those found automatically by the deep learning framework. Input-perturbation with output probability correlation was used to visualize the salient features. Data samples with the highest probability per class were compared with ‘baseline eyes open’ to understand what the CNN learns in each class. The ultimate goal is cataloging of dynamic brain patterns associated with mental states underlying creativity, and developing computational models that take real-time neural EEG input and predict evolving behavioral actions.

ID: 20 / Presentation: 20
Invited Oral Presentation
Session: Neuroarchitecture, Performing Arts & Dance

Rhythm and the Embodied Sense of Space

Sha Xin Wei[1]

[1]Arizona State University, Arizona, USA

Abstract: We report on how people acquire a sense of spatial relation to each other and to our media rich environment. We call this sense *spatiality*, after Merleau-Ponty's treatment which resorts neither to physical abstractions external to subjective experience, nor to purely mental phenomena. Note: (1) Relationality motivates Leibnizian, Riemannian approaches rather than the Euclidean model in conventional computational abstractions. (2) The *sense* of space requires taking subjective experience as primary data rather than subject-independent measures (such as clock time or "objective" sensor data), which requires phenomenologically informed methodology. (3) Since people and events always vary, spatiality is inextricable from temporality. When we see a child about to jump over a skip rope held by friends, we see characteristic pre-accelerations that entrain the person to the anticipated time-varying, spatial relations. Since people's experiences are mediated via *bodies* in *physical* environments, and given that people's experiences are dynamical, it's natural to particularize the question of spatiality to the question of how bodies move across inhomogeneous extension to produce a sense of *rhythm*. We will suggest that (1) rhythm is not sense data; (2) biosocial rhythm is not perfectly periodic; and (3) rhythm is not unidimensional. We invite colleagues from neuroscience and bio-engineering to construct experiments in whole-body interaction of ensembles of three or many people, joining brain data with movement or gestural data modulating the rich but precisely reproducible qualia ("feedback") of responsive media environments.

ID: 21 / Presentation: 21
Invited Oral Presentation
Session: Neuroarchitecture, Performing Arts & Dance

Joint action aesthetics in live dance performance

Guido Orgs[1]

[1]Goldsmiths University of London, London, United Kingdom

Abstract: Synchronizing movements between individual performers is a central aspect of performing dance and music. In two experiments, we investigated performing and perceiving synchrony in live dance performances. In a live theatre setting, participants performed a set of movement tasks that were either performed as a group or individually. During execution (dancers) and observation (spectators) of these tasks, we assessed movement synchrony based on performer acceleration and spectators' psychophysiological responses using wrist sensors. We also recorded continuous ratings of aesthetic appreciation and perceived group characteristics. We show that movement synchrony is associated with group affiliation among performers and predicts spectators' heart rate and enjoyment. Our findings point to an evolutionary function of dance – and perhaps all performing arts – in communicating social signals between groups of people.

ID: 22 / **Presentation: 22**
Invited Oral Presentation
Session: Neuroarchitecture, Performing Arts & Dance

What if the brain was inside a violin? From musician's to dancer's expression

Hanna Poikonen[1]

[1]University of Helsinki, Helsinki, Finland

Abstract: Music and dance have been important parts of the human experience for millennia. They have enabled interaction which has given rise to resilient communities and rich cultures. Neuroscience has studied music for decades, but only recently the interest has been directed to dance. Studies of professional dancers and musicians have highlighted the importance of multimodal interaction and motor-related brain regions in cerebral processing of dance and music. In my PhD research, I studied cortical processes of professional dancers, musicians and laypeople when they were watching video-recorded dance piece *Carmen* in an EEG laboratory. I linked Motion Capture data of the performing dancer to the EEG data of the spectators. During the choreography with fast large movement, the alpha phase synchrony decreased in all study groups when compared to the parts of the choreography with nearly still presence. In addition, dancers had stronger theta phase synchrony during audio-visual dance performance when compared to musicians and laypeople. Dancers also had stronger early ERP response (P50) during fast changes in musical brightness when compared to musicians and laypeople. When discussing the different brain processes related to expertise in dance, it is crucial to understand the essence and versatility of the dance training. Neuroscience of music has shown differences in the brain functions between jazz and classical musicians; pianists, percussionists and violinists; and improvisation based on emotion and chords. Similar differences between the subgroups are expected to be found in the brains of the dancers.

ID: 23 / Presentation: 23
Invited Oral Presentation
Session: Neuroarchitecture, Performing Arts & Dance

Rhythms in Music and Brain

John Iverson[1]

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Abstract: Every human culture has some form of music with a beat: a perceived periodic pulse that structures the perception of musical rhythm. Is beat a purely auditory phenomenon? We propose ‘no’: the motor system plays a necessary role in dynamically shaping our perception of rhythm through bidirectional auditory-motor signaling, as laid out in the ASAP (action simulation for auditory perception) hypothesis (Patel & Iversen, 2014). The beat music is not uniquely determined by sound, but is an endogenous response to music that can be shaped at will by the listener, dramatically changing the perceptual experience of a rhythmic pattern. Accordingly, brain responses to an ambiguous rhythmic phrase were measured while listeners voluntarily altered where they perceived the ‘downbeat,’ leading to different highly syncopated rhythm percepts from which beat and sound could be temporally dissociated. MEG recordings with ICA identified multiple cortical effective sources of activity in each participant, differentiating beat- and sound-responsive regions in premotor and superior temporal cortex, respectively, consistent with ASAP. Recently (Ross, et al, 2017) we used neurostimulation to more directly test the role of the motor system in beat perception. Transient reduction of activity in parietal cortex, a critical link between auditory and motor systems, was associated with reduction of beat-detection performance, consistent with ASAP. The talk will include brief discussion of the implications of the results for the evolution of beat perception in humans (Iversen, 2016) as well as future MoBI projects in this area.

ID: 24 / Presentation: 24
Invited Oral Presentation
Session: Sports- and Movement Sciences

Directional tuning and reference frames in human pointing

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Abstract: Recent developments in EEG recording and signal processing have made it possible to record in an unconstrained, natural movement task, therefore EEG provides a promising approach to understanding the neural mechanisms of upper-limb reaching control. This study specifically addressed how EEG dynamics in the time domain encoded finger movement directions (directional tuning) and posture dependence (movement reference frames) by applying representational similarity analysis. High-density EEG covering the entire scalp was recorded while participants performed eight-directional, center-out reaching movements, thereby allowing us to explore directional selectivity of EEG sources over the brain beyond somatosensory areas. A majority of the source processes exhibited statistically significant directional tuning during peri-movement periods. In addition, directional tuning curves shifted systematically when the shoulder angle was rotated to perform the task within a more laterally positioned workspace, the degree of tuning curve rotation falling between that predicted by models assuming extrinsic and shoulder-based reference frames. We conclude that temporal dynamics of neural mechanisms for motor control can be studied noninvasively in humans using high-density EEG and that directional sensitivity is not limited within the sensorimotor areas but extends to the whole brain areas.

ID: 25 / Presentation: 25
Invited Oral Presentation
Session: Sports- and Movement Sciences

Neuromuscular control in clinical and athletic populations: science of past and future

Angus Hunter[1]

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Abstract: Motor unit (MU) recruitment strategies are thought to produce safe, economic contraction of skeletal muscle via the Central Nervous System (CNS) to protect muscle integrity and whole-body health. Extensive studies by colleagues and ourselves have provided further knowledge surrounding MU recruitment strategies employed under different environmental and pathological conditions; i) Subconcussion demonstrate cortico-spinal inhibition and altered MU recruitment strategies; ii) Multiple Sclerosis patients demonstrated reduced MU recruitment with increased muscle fibre conduction velocity (MFCV); iii) exercise induced hyperthermia reduced MU recruitment and preserved MFCV; iv) eccentric overload reduced firing rates of high threshold MU and; v) damaging eccentric exercise showed recovery of force coupled with higher threshold motor unit firing. These novel studies have provided greater information regarding motor unit recruitment strategies but the mechanisms of brain function, via the CNS, remain elusive. The rapid evolution of mobile cognition technologies such as mobile; EEG, EMG; electrogoniometry; and foot force pressure sensors are now providing further opportunities to explore brain function in relation to neuromuscular recruitment strategies. The benefit of these technological advances in our understanding are, for the time being, limitless particularly as there is now increasing evidence of a mismatch between data obtained in the lab versus that in the field. Understandably this has significant implications for translation of lab studies into that of the clinical and sports performance areas. This provides a wealth of applications and opportunities for neuromuscular science of the future.

ID: 26 / Presentation: 26
Invited Oral Presentation
Session: Sports- and Movement Sciences

Motor fatigue and prefrontal cortex correlates during dual task fine motor control

Nadja Schott[1]

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Abstract: The effects of exercise-induced fatigue on cognitive functions such as working memory, attention and visual-information processing speed vary and depend upon exercise duration and intensity, and the type of cognitive tasks assessed (Moore et al., 2012). To explain the detrimental effects of exercise upon cognition Dietrich and Audiffren (2011) proposed the reticular-activating hypofrontality hpothesis, which makes a decrease in frontal neural activity responsible, in favor of brain regions associated with sensory and motor processes. In young adults, the empirical evidence for hypofrontality during exercise has been mixed, indicating either negative or positive effects of exercise (e.g., Chu et al., 2017; Davranche et al., 2015; Del Giorno et al., 2010; Pesce et al., 2003; Schmit et al., 2015; Wang et al., 2013). Most of these studies used shorter and mostly less challenging exercise protocols; no studies have examined prolonged exercise protocols until exhaustion (> 20 min). The aims of this study are: (1) to examine the effect of a concurrent cognitive task on fine motor task performance in adults (before, during and after a prolonged motor fatiguing protocol), (2) to determine whether the effect varied with different difficulty levels of the concurrent task, and (3) to measure oxygenation of the prefrontal cortex associated with different levels of task difficulty. We examined this knowledge gap by measuring cognitive control and cerebral oxygenation during high-intensity interval exercise (HIIE) or a moderate-intensity continuous exercise (MCE) protocol. Participants were monitored using prefrontal near-infrared spectroscopy during the completion of a modified (digital) Trail-Making-Test (TMT) at rest or while cycling on a stationary bicycle at either 4 x 4min high-intensity bouts at 90% of the VO_2max, separated by 3min of moderate intensity (60% of the VO_2max) or 30min at 60% of the VO_2max. Cognitive performance was performed 2min into the exercise protocol at 60% of the VO_2max, again after the exercise intervention, and after a 10min recovery period. In addition to the typical TMT (A serial connection of numbers (1–25); B serial connection of numbers (1–13) and letters (A–L) in an ascending number-letter sequence (1-A-2-B- etc)) we have included a motor speed trail-tracing-task allowing us to calculate dual-task effects. Furthermore, the digital version of the TMT (e.g., time in circles, pauses, lifts, time between circles) allows us to isolate cognitive processes believed to be important in TMT performance. In this talk, we will present and discuss behavioral and neural data from young adults, and athletes with and without prior concussion.

ID: 27 / Presentation: 27
Invited Oral Presentation
Session: Sports- and Movement Sciences

The neural underpinnings of superior kicking performance in skilled soccer players

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Abstract: World football/soccer is considered as one of the most popular sports in the world. Soccer players like Christiano Ronaldo, Lionel Messi and Neymar consistently impress millions of people world-wide with their skills. However, despite recent progresses in mobile brain imaging, only very little is known about the neurophysiological processes that support high achievement in soccer. Further advancing our knowledge about such processes is important for a better understanding of neural plasticity associated with participation in different sports, and it may also have important implications for the further development of effective training interventions. We addressed this knowledge gap by measuring electroencephalographic (EEG) activity in skilled soccer players and non-soccer athletes during preparation of various ball kicking tasks differing with respect to ball dynamics (stationary vs. approaching) and the relevant performance measure (accuracy vs. speed matching) in an ecologically valid setting. Using independent component analysis and clustering, a central, a left parietal and a parieto-occipital cluster of components were identified. More accurate kicking performance in soccer players was associated with a significantly different pattern of event-related spectral perturbations in a cluster-dependent and task-specific manner. This study indicates that is feasible to identify cortical regions relevant for the preparation of complex soccer skills in a real-word environment with as few as 15 active EEG channels. Furthermore, the results provide new insights into brain processes associated with skilled soccer actions.

ID: 28 / **Presentation: 28**
Invited Oral Presentation
Session: Sports- and Movement Sciences

Neural generators and brain states in real-world tightrope walking

Guy Cheron[1]

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Abstract: A modern neuroscience consensus concluded on the importance of three basic research questions: “what makes individual brains unique; how brain’s many components orchestrate learning and perform a task; and how to leverage the brain’s plasticity to protect and restore brain function?”(Underwood, 2016). In this context, the reactivity of the EEG signals has been mainly studied in response to sensory input or during cognitive task but less often during motor behaviour. As the EEG signals represent the dynamics of the brain states resulting from synchronous neuronal activity of local field potentials distributed into temporal and spatial coordinated networks of neurons, it is important to quantify in the EEG signals the part of this activity devoted to its downstream impact on motor behaviour. Based on the idea that the uniqueness of the individual brain is all the more evident that it is accompanied by an exceptional performance, we recently begun the experimental search of psychological “flow”. This singular brain state emerges from an action requiring clear goal and a perfect match between specifics skills and challenge (Csikszentmihalyi, 1975; Mao et al., 2016; Cheron, 2016). Amongst different sports, the tightrope walker activity appeared as particularly attractive because the highly restrictive field of action requiring optimal balance control permanently exerted at the edges of the fatal fall. What about the brain of a tightrope performer during this performance? How to reach the brain dynamics of a subject situated on a cable at an altitude of 30 meters? We here report this analysis on Oliver Zimmerman’s brain by using high density electroencephalography (EEG), coupled to electro-oculography (EOG), electrocardiography (ECG) and electromyography (EMG) recordings before and during walking on a long cable (100 m) placed at an altitude of 30 meters. The neuronal generators of the different EEG oscillations were studied by means of inverse modelling (swLORETA) showing along this performance the respective contribution of different cortical areas, the basal ganglia and the cerebellum.

ID: 29 / Presentation: 29
Invited Oral Presentation
Session: Therapeutic Interventions

A Revitalized Synthesis: Art Therapy, Neuroscience and Mobile Brain/Body Imaging

Juliet King[1]

[1]George Washington University, Washington, USA

Abstract: Since its inception in the 1940's, the field of art therapy has intuited the connections between artistic expression and brain processes with the identification of three primary tenets, all of which can be underscored with neuroscience principles: (1) the bilateral and multidirectional process of creativity is healing and life enhancing; (2) the materials and methods utilized affect self-expression, assist in self-regulation, and are applied in specialized ways, and (3) the art making process and the artwork itself are integral components of treatment that help to understand and elicit verbal and nonverbal communication within an attuned therapeutic relationship (King, 2016). However, without empirical evidence to prove these tenets, art therapists rely on interpretive frameworks, which are often anecdotal, idiographic, and do not allow generalizations to be made for larger populations. The purpose of this talk is to discuss trans-disciplinary research on how brain science and artistic processes inform one another to support the overall health and amelioration of disease for patients in need of psychological and medical care. Exploring the biological basis of creative arts and neuroscience through the use of Brain-Computer Interface and Mobile Brain-Body Imaging (MoBI) techniques will promote a greater understanding for the capacities of the creative arts therapies to be considered an effective and data-driven medical and mental health profession. Simultaneously, creative arts therapists are positioned to uniquely inform research scientists of the implications of non-verbal, sensory based and symbolic expression within a therapeutic and clinical context.

ID: 30 / Presentation: 30
Invited Oral Presentation
Session: Therapeutic Interventions

How does art therapy work? Identifying clinical processes and ways to measure change

Girija Kaimal[1]

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Abstract: Art therapy interventions have been found to result in positive health outcomes like improved mood, self-efficacy and creative agency, as well as, lowered anxiety and stress. In addition, in narrative responses, participants have indicated that the therapeutic interaction with an art therapist helps them view experiences through new perspectives, experience positive emotions, develop a stronger sense of identity, externalize debilitating ruminative processes, distract from negative perceptions, and, improve focus and attention. Despite these outcomes, mechanisms of change through art therapy remain poorly understood. Mobile brain imaging technologies like functional near-infrared spectroscopy (fNIRS) could help identify some of these mechanisms especially since they generate measurements of processes in naturalistic settings including those of art-making in the context of a therapeutic session. FNIRS has been used to assess reward perception as related to different drawing tasks like doodling, coloring and free drawing. It has also been used to determine patterns and brain signatures in psychological health conditions like schizophrenia, depression, and, suicidality. The use of fNIRS is still emergent and has been limited by the inconclusive interpretations of the hemodynamic response. This presentation will describe art therapy treatment approaches for diagnoses like for eating disorders, mood disorders, and post-traumatic stress and examine if and how MoBI technologies like fNIRS might be used to understand mechanisms of change. The presentation seeks to generate discussion around clinical constructs from art therapy and how they can be linked to the technological capabilities of MoBI.

ID: 31 / Presentation: 31
Invited Oral Presentation
Session: Therapeutic Interventions

Measuring brain mechanisms underlying dance-therapy: past & future directions

Tal Shafir[1]

[1]University of Haifa, Haifa, Israel

Abstract: According to Damasio, when the current state of the body is conveyed to the brain by afferent input from the body, the resulting brain activation patterns represent unconscious emotions, which are experienced as subjective feelings. This implies that deliberate control of motor behavior could help regulate feelings through proprioceptive input. Indeed, we demonstrated that execution, observation and imagination of various whole body emotional expressions differentially activate emotional processing regions in the brain and enhance specific emotions. These principles are used in dance-movement therapy, when therapists observe and mirror clients' movements to empathize with them, or encourage clients to engage in specific movements, to help them experience and process associated emotions. But which movement evokes which feeling? Using Laban Movement Analysis we identified unique sets of movement components (characteristics) whose execution enhances different emotions. Moreover, movements composed of components associated with specific emotions were recognized above chance level as expressing those emotions, even when movers did not intend to express emotions, and emotion elicitation using recall of autobiographical memories led to whole-body emotional expressions composed of mainly those same movement components. An additional study using Kinect and machine learning techniques suggested a biofeedback system able to identify these movement components from people's movements based on their 3D data. Based on these past findings and methodologies, we will present our vision and invite colleagues to join a future collaborative study aimed to further uncover the underlying brain mechanisms for movement-emotion interaction, using mobile EEG, 3D data, machine learning, and Laban experts as movers.

ID: 32 / Presentation: 32
Invited Oral Presentation
Session: Therapeutic Interventions

Communication and Creative Expression: Biodata as Technological Mediation

Stephanie Scott[1]

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Abstract: This project explores the relationship between EEG and artistic engagement to examine how neural oscillations and modifications may contribute to meaningful self-expressive communication processes. It investigates how biodata and neurofeedback can be integrated into the architectural design of digital spaces that are designated for artistic expression, and how these applications might be valuable for evaluating meaning-making and learning outcomes for current users of Brain-Computer Interfaces (BCI) and Mobile Brain Body Imaging (MoBI) systems. Conceptually, these efforts are designed to promote collaboration, artistic self-awareness, rehabilitation and recovery for people with limited mobility and limited resources for self-expressive forms of communication. Additionally, this work explores how applied communicative theoretical frameworks and Human-Computer Interface (HCI) concepts may further promote potential therapeutic opportunities. It looks to extend the lens for transdisciplinary efforts to include art, technology and therapy, and questions how this integration may enhance communication within existing channels of language behaviors for users. With a focus on using complex technologies to provide innovative contributions to therapeutic care, it asks how we may pragmatically apply the principles of attention and engagement within this space, and translate these notions into action. Ultimately, this work poses the question of how technology can best be used to mediate social expression.

ID: 33 / Presentation: 33
Invited Oral Presentation
Session: Therapeutic Interventions

EEG imaging in young adult twins with autism spectrum disorder and ADHD

Gráinne McLoughlin & Jason Palmer[1]

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Abstract: In young adulthood, the brain begins the final stretch of its development. This process is crucial to making the leap to an adult mature state. However, there are individual differences in social and attentional processing, which are key to improved well-being and quality of life. Application of advanced signal processing to temporally-rich EEG data can provide highly sensitive markers of cognitive function that may have a genetic influence. We have previously shown this in a twin study through the identification of functional measures that explain more genetic variance than standard EEG. It is currently unclear how brain function in early adulthood influences emotional wellbeing, behavior and adaptive functioning and how much genes and environment contribute to this relationship. To answer these questions, we applied signal processing techniques to mobile EEG data from a large population-based twin study. Our sample consists of 480 individuals (240 twin pairs) aged between 21 and 24 from across the UK. Our findings mirror earlier results in that we find very distinct differences between ASD and ADHD in social processing measures, yet some overlap in attentional processing. Our key finding is that deficits in social processing share genetic influences with wellbeing and social adjustment in early adulthood. We anticipate that this work will pave the way for identifying optimal treatment targets for these disorders and the design of more specific interventions to prevent emotional and mental health problems from developing. The innovative use of mobile EEG has the potential to transform neurophysiological research and routine clinical evaluation for psychiatric disorders.

ID: 34 / Presentation: 34
Invited Oral Presentation
Session: Therapeutic Interventions

Mobile EEG for neurofeedback training at home in chronic stroke

Conny Kranczioch[1]

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Abstract: Motor imagery (MI) with neurofeedback is a promising add-on therapy for motor recovery after stroke. Regular training with MI neurofeedback should facilitate compensatory plasticity and motor rehabilitation, but due to the machinery involved, translating regularity into training protocols has been difficult so far. Based on a number of studies in healthy younger and older adults we implemented a frequent and efficient neurofeedback training that was run at patients' homes. Patients imagined a simple hand movement and neurofeedback that was based on data collected with a wireless electroencephalogram (EEG) system. Three chronic stroke patients practiced every other day over a 4-week period and participated in pre- and post-training assessments of behavior, function, and structure. One patient showed a substantial clinical improvement of upper limb motor function that was associated with a significant change in EEG lateralization and paralleled by additional changes in function and structure. Two patients showed no clinical improvement in motor function. However, for them, EEG activity induced by MI of the paretic hand became likewise more lateralized towards the ipsilesional hemisphere over the course of training, yet to a smaller degree. Though preliminary, these results show great promise for the benefit of mobile, wireless EEG for neurorehabilitation applications.

ID: 35 / Presentation: 35
Invited Oral Presentation
Session: Neuroergonomics

Assessing mental states in real life workplace scenarios

Edmund Wascher[1]

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Abstract: Mental states, like boredom or fatigue, are among the main accident hazards in many work environments. Attentional withdrawal may lead to impaired information processing and consequently to processing errors. Understanding mechanisms and causes of reduced task engagement is therefore an essential issue for work safety. In the laboratory, increased power in the lower frequency bands of the EEG has turned out to be a valid indicator of attentional withdrawal. Applying these measures to more realistic scenarios, by means of mobile EEG, revealed a broadband reduction of oscillatory power. This broadband reduction, however, appears to mask specific spectral effects, as it seems to reflect primarily neural noise. Based on recent data we try to evaluate new measures, which are tailored towards representing cognitive effects in specific frequency bands. Our aim is to estimate mental states in realistic environments and to be able to detect phases of reduced attentional engagement.

ID: 35 / Presentation: 35
Invited Oral Presentation
Session: Neuroergonomics

How looming sounds capture and sustain our visual attention during steering

Christiane Glatz, Marie Lahmer, Makoto Miyakoshi, **Lewis Chuang**[1]

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Abstract: Whilst driving, we attend to the road to ensure that we stay on it. Nonetheless, unexpected events might demand our immediate attention instead; for instance, the sudden appearance of collision hazards or jaywalkers along the road. As we approach such objects, they loom, which is to say that they increase in retinal size. Also, they might emit looming sounds, which increase in loudness. Our brains respond preferentially to looming stimuli; past research has primarily focused on multisensory integration or crossmodal influences. In my talk, I will present our investigations on how looming sounds could influence visual attention in steering environments. The first study was performed in a driving simulator whereby we found that looming sounds promoted faster braking times to the unexpected appearance of collision objects, relative to comparable sounds. EEG analyses revealed that differences in the activity of BA6 underlie this performance benefit, suggesting that looming sounds heighten arousal and preparatory activity for braking responses. In a second study, we show that auditory looming cues resulted in faster discrimination of peripheral visual targets during a continuous visuo-motor steering. EEG analyses suggested two complementary networks of preferential activity for looming over static auditory cues (BA23, BA19, and BA7) and for static over looming auditory cues (BA8, BA45, and BA10). Respectively, they suggest that looming cues promote voluntary spatial orienting and experience less inhibition in prioritising this over the primary steering task. To sum, looming sounds help us to attend appropriately to objects that we might collide with during steering.

ID: 36 / Presentation: 36
Invited Oral Presentation
Session: Neuroergonomics

Using EEG to study brain dynamics in car driving

Christer Ahlström[1]

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Abstract: Human behavior is a contributing component in up to 94% of vehicle crashes. A common “solution” is to attribute these crashes to human error and settle with that. A more productive way forward is to define human behavior as a product of its settings, where a suitable vehicle and working environment will enable the drivers to act with a minimized probability of error. It comes without saying that in this latter approach, a detailed picture of driver behavior is needed. This detailed picture is usually obtained by evaluating driving performance, reaction times and glance behavior, where foveal vision is used as a proxy for attention. To get a fuller picture of what is happening inside the driver’s head, we have found it useful to complement these measures with EEG data. This presentation will provide an overview of our EEG research in car driving. This includes the development of a close to real-time algorithm for artifact handling that has been tailored to active individuals in a driving setting, an investigation of local sleep in car drivers where signs of sleep need (theta content) in source localized motor-related parts of the brain preceded lane departures, the relation between cognitive overload and eye fixation related potentials (EFRP), and finally that underload reduces attention allocation when driving semi-automated vehicles. All in all, EEG information has helped us to get a richer understanding of driver behavior which eventually will help us reduce the number and severity of crashes.

ID: 37 / Presentation: 37
Invited Oral Presentation
Session: Neuroergonomics

Towards next-generation clinical brain/neural-machine interfaces

Surjo Soekadar[1]

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Abstract: Today, five out of ten diseases worldwide resulting in long-term disability are related to the central nervous system. Due to the immense complexity and inter-individual variability of the human brain there are still no effective treatment options for many serious neurological and psychiatric disorders such as stroke, major depression, schizophrenia or dementia. Recent advancements in sensor technology and computational capacities resulted in the development of brain/neural-machine interfaces (BNMIs) that translate electric, magnetic or metabolic brain activity into control signals of external devices, robots or machines. Moreover, novel transcranial magnetic and electric brain stimulation (TMS/TES) systems were developed allowing for direct modulation of brain activity. However, current BNMIs are limited by the low information extraction rate constraining fluent direct brain-computer interaction. Furthermore, as simultaneous assessment of brain oscillations during TES was regarded unfeasible due to stimulation artefacts, current TES systems can only deliver "open-loop" stimulation unrelated to the underlying dynamic brain states resulting in highly variable TES effects. The talk will describe how combing both techniques into a neuroadaptive BNCI might overcome these limitations and lead to new and more effective treatments strategies for neurological and psychiatric disorders. Besides addressing the feasibility of assessing brain oscillations during TES, the talk will also provide an overview of how BNMIs can be taken out of the lab, e.g. to restore activities of daily living after quadriplegia and improve motor function after stroke. The next steps towards the development and application of neuradaptive BNMIs will be depicted, and possible neuroethical dimensions discussed.

ID: 38 / Presentation: 38
Invited Oral Presentation
Session: Neuroergonomics

Exoskeleton-supported stroke rehabilitation using embedded brain reading

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Abstract: Stroke rehabilitation has to address many factors that are impaired by brain lesion caused by brain hemorrhage. Patients show diverse symptoms reaching from movement disorders, impaired sensation and cognitive deficits, which must be addressed by therapy. To compensate movement disorders, exoskeletons can be applied. They can sense movements and support them to enable a patient with smallest remaining muscular activity to regain control over a disabled limb. Electromyogram and force measurements can be used to adapt the support to the patients need. In case that no control of the limb is left, brain activity can be analyzed by embedded brain reading (eBR) to infer on the intention of the patient and to trigger movements implicitly. For a successful therapy not only assist as needed is required but further, patients must be able to follow instructions – mental stress must be avoided to assure optimal therapy conditions. Again, eBR can be used to detect task load on a patient while he or she is performing an ongoing action, e.g., performing a specific arm movement to infer whether a patient (while performing the movement) is still able to understand instructions by the therapist or a serious game. This presentation will show new therapy approaches for upper limb rehabilitation made possible by means of a newly developed exoskeleton with highly adaptive embedded control combined with movement intention recognition based on EEG, EMG and eye tracking data as well as task load detection based on P300 related activity under simple and multi-tasking conditions.

ID: 39 / Presentation: 39
Invited Oral Presentation
Session: Neuroergonomics

Passive Brain-Computer Interfaces for Neuroadaptive Technology

Thorsten Zander[1]

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Abstract: With increasingly powerful machines the asymmetry in the communication between men and machine has grown, but our interaction techniques have remained the same, resulting in a communication bottleneck. Passive Brain-Computer Interfaces (pBCIs) can assess brain activity resulting from cognitive processes related to the interaction and interpret them in real time. This information can then be used by the machine support its user reaching the goal of the interaction. This process does not require any action of the user, but transfers relevant information to the machine, widening the above-mentioned communication bottleneck. More general, this defines Neuroadaptive Technology – technology that automatically adapts to the current cognitive and affective state of its user. In the context of brain-computer interfacing, it thus is important to investigate what regions of the brain the chosen approach focuses on. For one, this will clarify to what extent the approach relies on brain activity, as opposed to undesirable non-cortical signals. More generally, the practice is informative as it allows conclusions to be drawn about the cortical regions—and thus, cortical functions—that contribute to the effect under investigation. I will discuss a method to visualise the regions of interest of standard BCI approaches. The method takes individually reconstructed source spaces and transforms the BCIs classifier filter weights into relevance weights indicating the relative contribution of each source to the approach. This is visualised across participants in an average brain. By decomposing the approaches weights into separate sources and localizing these in the brain, the method provides a tool to evaluate BCI approaches and test hypotheses. The method was tested on simulated data as well as on real data. We simulated two data sets of 10 simulated participants each. We ued the toolbox SEREEGA, short for Simulating Event-Related EEG Activity [3]. SEREEGA was written by Laurens Krol (Team PhyPA, TU Berlin) and is a MATLAB-based open-source toolbox dedicated to the generation of simulated epochs of EEG data. It is modular and extensible, at initial release supporting five different publicly available head models and capable of simulating multiple different types of signals mimicking brain activity. On both, simulated and real data, the method found the expected brain regions and provided a correct visualization. Visualisation methods, such as this one, enable us to compare a classifier's actual regions of interest to these hypotheses and validate our assumptions—and to gather new insights about the cortical processes underlying the observed effects. This allows to associate the BCI to specific cognitive tasks and design Neuroadaptive Technology purposefully.
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Poster Presentations

ID: 101 / **Poster: 15**
Poster Submissions
Topics: EEG, Sports- and Movement Sciences, Cognition and Motor Function, Gait- and Gait Rehabilitation
Keywords: Balance control, movement control, rehabilitation

Cortical dynamics of compensatory balance control

Teodoro Solis-Escalante[1,2], Joris van der Cruijsen[1], Digna de Kam[2], Joost van Kordelaar[2,3], Alfred C. Schouten[1,3], Vivian Weerdesteyn[2]

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Background. Although it is now accepted that the cerebral cortex participates in human balance control1, there is only limited knowledge about the cortical mechanisms that help maintaining standing balance2. Understanding these mechanisms is instrumental for the development of novel treatments to prevent fall-related injuries due to aging or neurological conditions (e.g., stroke)3. The aim of this study is to establish the cortical oscillatory dynamics of compensatory balance control, contrasting stepping and nonstepping responses to movements of the support surface.

Methods. We recorded high-density EEG from healthy participants, while they responded to backward movements of the support surface (Figure 1A-1B). Participants were instructed to maintain balance by taking a corrective step or keeping their feet in place (50 trials/condition, pseudo-random order), as indicated by a visual cue. We decomposed the EEG offline with independent component analysis4 and computed event-related spectral perturbations5 (ERSP) at group level, after clustering (k-means) independent components (ICs) across participants (based on scalp projection, associated equivalent current dipole, and power spectral density). We obtained mean time-frequency ERSP maps for each condition and compared them with permutation statistics (n=1000, two-tailed paired t-test, alpha=0.05, fdr corrected). Additionally, we computed mean time course and confidence intervals for theta, mu, and beta rhythms (bootstrap, n=1000, alpha=0.05).

Results. We found IC clusters (Figure 1C) near the supplementary motor area (SMA), anterior cingulated cortex (ACC), prefrontal cortex (PFC), posterior parietal cortex (PPC), and bilateral sensorimotor cortices (M1/S1). Full-body movement elicited power decrease of sensorimotor mu and beta rhythms in SMA, PPC, and bilateral M1/S1, irrespective of the response condition. Balance perturbations elicited broadband (3-17 Hz) power increase in SMA and theta power increase in ACC, PFC, PPC, and bilateral M1/S1, which were common to both response conditions. Noteworthy, theta power in PFC was stronger and longer-lasting during nonstepping behavior. Stepping behavior was distinguished by stronger lateralization of beta power decrease toward M1/S1 contralateral to the stance leg during single support.

Discussion. Distinct balance responses resulted in remarkably similar modulations of cortical rhythms in sensorimotor, premotor, and prefrontal areas, indicating the engagement of a cortical network for movement control. Lateralized beta activity in M1/S1 during single support could indicate cortical control of muscle contraction for stabilization of the stance body side. The common modulations of sensorimotor mu/beta rhythms (SMA, PPC, and bilateral M1/S1) could be partly related to direct cortical control over muscle activity, which may occur via neural synchronization6,7. In agreement with previous studies, we found broadband power increase in SMA8 and multifocal theta9,10 power increase immediately after movement of the support surface. These responses likely indicate the detection of a challenge to standing balance and the activity of a cortical network monitoring balance. Importantly, our results suggest that PFC is highly relevant for monitoring balance, because of its increased response under conditions of higher postural demand (feet-in-place responses). In future studies we will focus on evaluating the role of the cortical dynamics of compensatory balance control outlined here, with emphasis on the theta rhythm and causal corticomuscular connectivity during balance recovery.

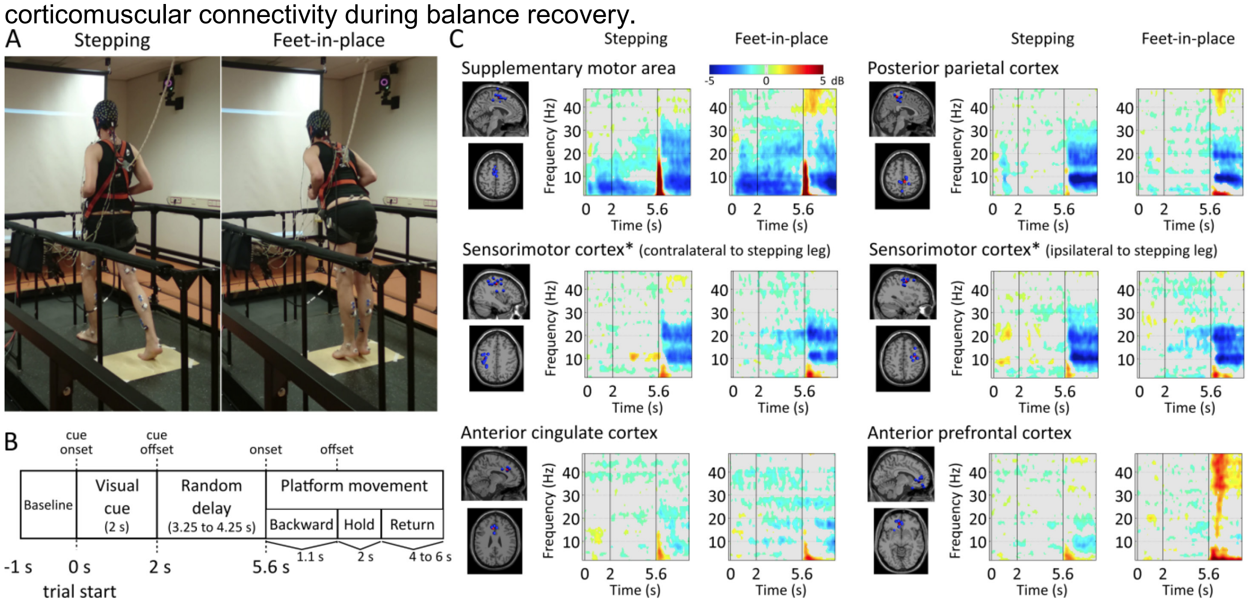

Figure 1. Experimental setup, trial timing, and event-related spectral perturbation maps. Healthy participants (n=10, age: 24±3.5 years) responded to balance perturbations with stepping and nonstepping responses (A), as indicated by a visual cue (B). The balance perturbations were backward movements of the support surface (300 ms acceleration, 500 ms constant velocity, and 300 ms deceleration) at a participant-specific acceleration (1.58±0.35 m/s2). Group-level ERSP maps (C) showed similar modulations of theta, mu, and beta rhythms during full-body movement and distinct compensatory balance responses. *Independent components from two participants who stepped with their left foot were manually removed from the lateralized sensorimotor clusters.

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ID: 103 / **Poster: 11**
Poster Submissions
Topics: Mobile EEG, Mobile Brain/Body Imaging, EEG, Synchronization
Keywords: BDM; eye-movement related potentials; value; source dipole analysis

The Application of Mobile EEG to the study of Product Preference Decisions; a Preliminary Investigation

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Background. Economic decisions occur when an individual uses subjective preferences to evaluate how much a product is worth. Little is known about the neural processes that underpin this form of decision making and EEG can inform us about when and where in the brain these decisions occur. The current study investigated the spatio-temporal dynamics that accompany economic valuation of products using mobile EEG and eye tracking techniques in the real world.

Methods. Participants viewed and rated images of products in a gallery setting while wireless EEG and eye tracking was recorded. A Becker-DeGroot-Marschak (BDM) auction task was subsequently used to measure willingness to pay for products, and this was used to retrospectively redefine economic value conditions. Eye movement related potentials (EMRPs) were examined and ICA was used to separate sources of activity from grand averaged EEG data. Isolated components of interest were back-projected and their relationship with subjective value was statistically analysed.

Results. EMRPs were reconstructed using five independent components. Four components were modulated by subjective value between 150 - 250 ms. IC6 showed an enhanced amplitude for high medium and low value products. IC4 displayed enhanced amplitude for all value conditions excluding low. IC7 presented enhanced amplitude for only low value items. IC3 revealed an initial enhanced peak for high medium products and a later enhanced peak for low medium products.

Discussion. Findings suggested that value-based decisions may not be computed in a linear manner. There may be an initial prioritization of attention towards low and high medium value products as these may represent more difficult decisions (IC6), followed by increased attention for high value products (IC4), low value products (IC7) and high and low medium values may be compared in succession at a later stage, as they may require more deliberation (IC3).

ID: 104 / **Poster: 13**
Poster Submissions
Topics: Mobile EEG, Mobile Brain/Body Imaging, EEG, Synchronization
Keywords: Mobile EEG Eye Tracking Face Perception

Brain responses to emotional faces in natural settings: a wireless mobile EEG recording study.

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Background. Previous fMRI and EEG studies have shown face-specific neural responses to faces compared to objects. Detection of face-specific brain activation in freely behaving and moving people has not been accomplished as of yet. The purpose of our research was to identify, using wireless multichannel EEG in freely moving participants, event-related potentials (ERPs) during viewing human faces.

Method. Mobile EEG and eye tracking was recorded from 19 freely moving participants whilst they viewed a mock art gallery. Stimuli were presented on 20 panels (A0 poster size) displayed in the ground floor of the psychology department building of the University of Liverpool. Positive, negative and neutral valence images were viewed and later rated by the participants. EEG was recorded continuously using a 64-channel BrainProduct MOVE system. In absence of triggers indicating onsets of viewing of visual stimuli, a novel PupilLab head-mounted wearable eye tracker was used to capture real world video recordings and the calibrated XY locations of the gaze. After synchronising the time sources of EEG and eye-tracking recordings, BESA 6.1. program was used to process EEG data.

Results. Wireless EEG recordings allowed identification of a face-related ERP component in the latency interval ranging from 165 to 210 ms (N170 potential); this component was not seen whilst participants were viewing non-living objects. The face ERP component was sensitive to the emotional face expression; in particular, the amplitude of N170 potential was stronger during viewing disgusted compared to neutral faces. Source dipole analysis revealed three equivalent current dipoles in the latency interval from 100 ms to 300 ms. Two source dipoles, located in the left extrastriate (BA19) and primary visual (BA17) cortex, modelled the visual P100 component, and one equivalent current dipole, fitted to the right fusiform gyrus (BA37), accounted for the face-related N170 potential.

Discussion. This study is the first to demonstrate the face-related ERPs in freely moving individuals in natural settings. The study opens new possibilities in clinical, developmental, social or marketing research in which information about presence of face perception and the type of perceived facial expression is of importance.

ID: 105 / **Poster: 24**
Poster Submissions
Topics: Analyses Tools, EEG, Gait- and Gait Rehabilitation
Keywords: Prosthetics, gait, dual-task walking

Cognitive performance and brain dynamics during walking with Ankle Mimicking Prosthetic Foot 4.0 prototype

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Background. An issue of bionic feet is the control of propulsive forces during walking. The brain plays a central role in human gait and, consequently, one of the solutions to optimize the control of bionic feet is neuroprosthetics, meaning that the prosthetic device is controlled by electrical muscular or brain signals. The acquired electrical signal is then used to optimize the movement of an artificial limb. A first step towards brain-computer interfaces of lower-limb prostheses is determining the supraspinal control of human locomotion. The aim was to investigate the attentional demand and electro-physiological brain measures during walking at normal speed in able-bodied individuals (CON), transtibial (TTA) and transfemoral amputees (TFA).

Method. 6 CON conducted one experimental trial, and 6 unilateral TTA and 6 unilateral TFA performed 2 experimental trials; the first with the current and the second with a novel prosthesis, i.e. the Ankle Mimicking Prosthetic foot or AMPfoot 4.0. Each experimental trial comprised 2 walking tasks; 6 and 2min treadmill walking at normal speed interspersed by 5min of rest. During 6min walking the sustained attention to response task was performed with measures reaction time (RT) and accuracy (ACC). Electro-encephalographic data were gathered when subjects walked 2min. Motor-related cortical potentials (MRCPs) and brain sources of MRCPs during gait were examined. Normality and (non-)parametric tests were conducted ($p<0.05$).

Results. Significant higher RTs were revealed for TFA with AMPfoot compared to CON ($p=0.020$). Further Mann-Whitney U tests revealed significant reduced ACC for TFA compared to CON ($p\leq0.009$) and TTA ($p\leq0.026$). Additionally, TFA showed significantly reduced ACC when wearing AMPfoot compared to the current prosthesis ($p\leq0.028$). No significant differences were observed for MRCP amplitude and latency measures between CON and TTA walking with the current or novel prosthetic device. No significant differences in brain source activity of the MRCP peaks were observed when TTA walked with the current and novel prostheses, as well as TTA walking with the current prosthesis compared to CON. On the other hand, compared to CON TTA wearing the AMPfoot showed significant higher activity of brain sources at the first positive deflection

Discussion. In contrast to TTA, TFA required more attentional demands during walking with AMPfoot compared to the current passive prosthetic device and CON. Since no significant differences were observed in MRCP amplitude and latency of any peak deflection, these electro-physiological fluctuations might be used to control of movement of the mechanical parts involved in propulsive forces of AMPfoot. The first positive electro-physiological deflection showed higher activity within the underlying brain sources in TTA walking with AMPfoot compared to CON, possibly due to the limited acclimation period to the novel device and consequently increased afferent sensory feedback signaling related to maintaining postural control.

ID: 106 / **Poster: 46**
Poster Submissions
Topics: Mobile EEG, EEG
Keywords: passive BCI, mobile EEG, usability

A DRY EEG SYSTEM FOR NEUROADAPTIVE APPLICATIONS IN REALISTIC AUTOMOTIVE SCENARIOS

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Background. To enable EEG measurement in mobile, real-world scenarios, sensor technology should be easy to apply, comfortable to wear and provide reliable, high-quality EEG signal. Recently, EEG systems with dry electrodes were developed. Dry sensors do not require conductive gel leading to reduced preparation time and sparing the user from washing gel out of their hair. We tested a dry EEG system in a realistic car environment regarding aspects of usability, measuring mobile EEG and real-world Brain-Computer Interfacing (BCI). These include accuracy and speed of cap self-application, quality of EEG signal compared to laboratory conditions, the extend of shifts in electrode positions induced by driving related movements, as well as wearing comfort and general usability of the EEG system.

Methods. Ten participants completed a four-staged experiment. Firstly, we investigated differences between application by an expert and self-application with regard to signal quality, cap positioning and time taken for application. At the second stage we recorded EEG from each participant once in a laboratory and in a stationary running vehicle. Participants completed two established experimental paradigms – an oddball (N200/P300 [1]) and a workload (alpha band power [2]) paradigm. In the third part participants performed different driving related movements sitting in the driver's seat of the vehicle. We measured the effect of these movements on the electrode positions. Finally, to assess the system's usability participants completed the System Usability Scale (SUS [3]) questionnaire. Participant also rated the level of comfort wearing the system on a 1 to 10 scale after each of the three experimental stages. In another questionnaire [4]. we assessed detailed aspects of wearing comfort and asked participants to mention any discomfort associated with wearing the system.

Results. We found no differences in application time and signal quality optimization between a trained applicator and self-application. BCI classification accuracies for both experimental paradigms were positively tested for equivalence. Movement execution resulted in electrode shifts of different extend: Head movements caused the strongest shifts, arm movements had less influence and whole upper body movements lead to the smallest changes. According to official SUS score interpretation, the system is slightly above the threshold of acceptability. Wearing comfort ratings decreased significantly with time. The questionnaire revealed bad scores for wearing comfort and pressure to the head. The system's weight was rated positively.

Discussion. We assessed different requirements to an EEG system for application in real-world driving scenarios. Results indicate that the system can be applied well by end-users without assistance of a trained expert. A BCI could be applied in both experimental conditions with similar reliability, as classification accuracies were found to be equal. As both, time and frequency domain features were evaluated, we conclude a general BCI applicability for the tested system. We found strong shifts in electrode positions

caused by movements, which could have an effect on the EEG in real-world use – current ongoing work is investigating this question [5]. Regarding the usability of the system it is on the edge of acceptability. The reported discomfort while wearing the system is unacceptable though and needs improvement.

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ID: 107 / Poster: 20
Poster Submissions
Topics: EEG, Cognition and Motor Function
Keywords: Joint Action, Feedback Related Negativity, Action Monitoring, Cooperation & Competition

Dynamics of feedback processing in cooperative and competitive situations.

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Background. People performing joint actions may cooperate or compete to achieve their joint or individual goals. In the present study, we investigated the neural processes underpinning error and monetary rewards processing in such situations using the EEG. We analyzed event-related potentials (ERPs) triggered by feedback about individual and joint actions in cooperative and competitive situations. Given previous literature, we hypothesized monetary losses will elicit more negative responses at midline frontal electrodes (Feedback Related Negativity (FRN)) than monetary wins without regard to the social situation. Additionally, we expected that processing of feedback might be modulated by the social situation (cooperative and competitive).

Methods. Twenty pairs (N=40) of participants performed a joint four-alternative forced choice (4AFC) visual task either cooperatively or competitively. At the end of each trial, participants received visual performance feedback and accompanying monetary rewards. Specifically, the feedback included individual and joint errors. Furthermore, the resulting positive, negative or neutral monetary rewards were dependent on the social situation. This design rigorously instructed participant to cooperate or compete due to the pay-off matrix.

Results. Preliminary analysis of the EEG data revealed the main effect of the valence of the outcome at midline frontal electrodes. This component (FRN) was more negative for losses than wins in both social situations. Moreover, our results suggest that the FRN might be modulated by different social situations.

Discussion. In sum, our results replicate previous studies about the FRN and extend them by comparing neurophysiological responses to positive and negative outcomes in a competitive situation, which simultaneously engage two participants. Furthermore, the present design allows for within participants comparison between different social situations (cooperative and competitive). Results of this comparison suggest that the FRN is modulated by social situations. These results can shed new light on the neural process underpinning error and reward processing in cooperative and competitive situations.

ID: 108 / **Poster: 25**
Poster Submissions
Topics: Analyses Tools, Neuroergonomics
Keywords: Movement Segmentation, Exoskeleton, Movement Analyses, Online Labelling

Automatic Movement Segmentation of Exoskeleton Data

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Background. We present a method to automatically segment manipulation movement demonstrated with an exoskeleton into distinct action units. The automatic segmentation of movement plays an important role in applications such as robotic learning from demonstration [4], as well as in braincomputer interfaces when labels for machine learning methods are needed, e.g. for movement prediction [8]. The presented segmentation method is motivated by the hypothesis that human movement is composed of simple building blocks which can be combined to complex behavior [2]. In manipulation movements, these building blocks are characterized by a bell-shaped velocity profile of the hand [5]. We use this to segment human movement trajectories of manipulation tasks into movement building blocks.

Method. We developed the velocity-based Multiple Change-point Inference (vMCI) algorithm to segment movement trajectories into building blocks characterized by a bell-shaped velocity profile [6]. The algorithm detects segment borders using Bayesian Inference and an on-line Viterbi algorithm. By including the assumption of a bell-shaped velocity into the inference, we are able to segment movement trajectories automatically without need for parameter tuning, as shown in different experiments [6, 3]. To segment movements demonstrated with an exoskeleton, the recorded joint angle data is transformed into Cartesian coordinates of the end-effector using forward kinematics. We recorded a demonstration of one subject wearing the exoskeleton developed in the project Recupera REHA [1]. The subject performed several point-to-point movements with the right arm. We segmented the data based on the position and the velocity of the end-effector.

Results. The algorithm successfully found movement segments with a bell-shaped velocity profile in the recorded data. Figure 1 shows a representative part of the segmented demonstration. The segments were found without need for data preprocessing and without any parameter tuning. However, some of the movements corresponding to a single point-to-point movement were segmented into two segments instead of one, mainly caused by decelerated movements likely induced by a movement restriction through the exoskeleton.

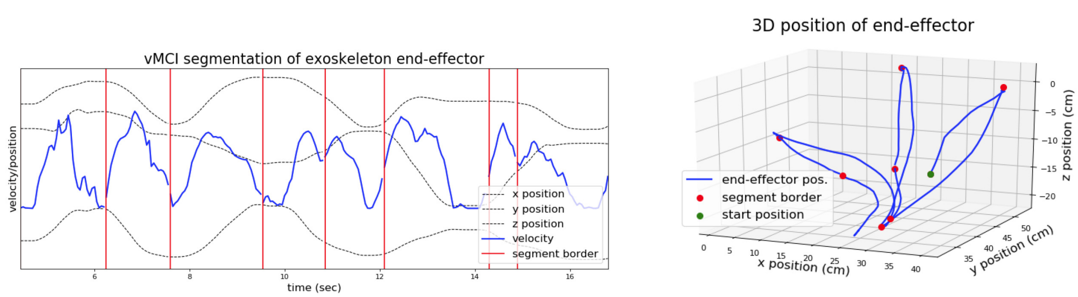

Figure 1: Segmentation results of point-to-point movements demonstrated by a subject wearing an exoskeleton. The right arm was moved from a rest position to 3 different positions (right side).

Discussion

We demonstrated the vMCI method for movement segmentation of exoskeleton data. Compared to threshold based methods 7. there is no need for parameter optimization or preprocessing of the recorded data. Furthermore, the proposed algorithm can be run online. This makes the method suitable for online and embedded systems with low computational resources. Besides the generation of training labels for, e.g. classifiers for biosignal based movement prediction, the algorithm can also be used for an online adaption of these kinds of classifiers. The concatenation of movement segments consisting of two bell-shaped curves but belonging to the same movement class should be investigated in future work.

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ID: 109 / **Poster: 5**
Poster Submissions
Topics: Mobile EEG, Analyses Tools, EEG, Synchronization
Keywords: ERP, P300, Fatigue, Mobile EEG, PEER

Using Mobile EEG to Quanitfy Physician Fatigue

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Background. Medical mistakes made during the fatigue state result in the spread of infection, diagnostic error, psychological distress, poor patient outcomes, and ultimately loss of life. Alarmingly, the fatigue-management systems put forth by government agencies have failed to reduce the risks of fatigue in physicians. A shift from "one size fits all" approaches for fatigue management, to individualized fatigue assessment and training, is required. To date, no validated measures of fatigue are feasible for use as portable, on-site assessments. Interestingly, previous research has shown that electroencephalography (EEG), and specifically the event-related brain potential (ERP) technique may provide a viable methodology for fatigue assessment. For example, work by Hopstaken and colleagues (2014) demonstrated that mental fatigue was associated with a reduction in the amplitude of the P300 ERP component. Here, we used the MUSE EEG headband (InteraXon Inc.) combined with the recently developed iOS PEER application (Suva Technologies Inc.) to validate whether or not a mobile EEG platform could be used to quantify fatigue. Specifically, we sought to demonstrate that fatigue would be associated with reductions in the amplitude of the P300 ERP component measured on a mobile platform.

Methods. Two groups of participants were tested. The first group ($n = 100$) were university aged students at the University of Victoria. The second group ($n = 24$) were emergency doctors at the Royal Jubilee Hospital in Victoria, B.C. Both groups completed a brief state fatigue survey prior to EEG data collection. For EEG data collection, both groups completed a simple visual oddball paradigm using the PEER application which concurrently was recording EEG data streamed from a MUSE EEG headband. Following data collection, ERP data were analyzed using standard analysis procedures we have validated elsewhere (Krigolson et al., 2017).

Results. For both groups of participants we found that we were able to quantify the P300 ERP component using the MUSE EEG headband and the PEER application. More importantly given our hypotheses, an analysis of the ERP data for both groups revealed significant correlations between P300 amplitude and rated measures of mental fatigue. Specifically, for the first group of participants we observed a Pearson $r = -0.44$, $p < 0.001$ and for the second group of participants we observed a Pearson $r = -0.56$, $p < 0.001$.

Discussion. Here we demonstrate the viability of using a mobile EEG system and an iOS-based application to detect and quantify fatigue in medical doctors. Importantly, this research provides a basis for the development of objective protocols for fatigue assessment in medical environments – a standard which to date has not been met. Indeed, the development of objective measures of fatigue in medical environments (i.e., mobile EEG based) has the potential to improve patient safety and thus overall healthcare.

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ID: 110 / **Poster: 7**
Poster Submissions
Topics: Mobile EEG, Mobile Brain/Body Imaging, EEG, Cognition and Motor Function
Keywords: electroencephalography, virtual reality, balance control, electromyography, connectivity

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Electrocortical balance response to physical pull and visual rotation perturbations

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Background. Human balance control requires complex coordination and can lead to serious consequences if impaired [1]. Studies of balance training in older adults have shown the importance of cognitive activity in balance training [2], suggesting that cortical activity may provide an informative biomarker of balance performance. The purpose of this study was to use electroencephalography (EEG) to quantify electrocortical activity caused by both physical perturbations and visual perturbations that challenged balance to determine reliable cognitive signatures for assessing balance performance. From previous research, we expected perturbation-evoked theta-alpha (4-13 Hz) synchronization across many cortical areas [3]. We hypothesized that our visual perturbation would increase occipito-parietal theta alpha synchronization more than the physical pulling perturbation, and that the physical pulling perturbation would increase supplementary motor theta-alpha synchronization more than the visual perturbation. We also analyzed effective connectivity between cortical clusters, with the expectation that there would be increased connectivity to the anterior parietal area following perturbation onset due to increased sensorimotor processing.

Methods. We recorded 136-channel high-density EEG (BioSemi Active II) and 8-channel lower limb electromyography (EMG) from 30 subjects (15 males) during 10-minute trials of tandem standing and tandem walking at 0.22 m/s on a treadmill. Subjects were exposed to mediolateral physical pulling perturbations and visual field rotations presented by a virtual reality headset, synchronized with EEG data using Lab Streaming Layer [4]. We ran AMICA on the EEG data 5. and clustered the resulting equivalent dipoles into 8 cortical clusters [6]. We computed event-related spectral perturbation (ERSP) plots, with bootstrapping statistics to mask nonsignificant results. Using the SIFT toolbox [4], we fit multivariate autoregressive models to our cortical independent component activity and calculated partial directed coherence and directed transfer function. Phase randomized surrogate statistics and bootstrapping masked nonsignificant results.

Results. Cluster ERSP's showed theta-alpha synchronization after perturbation onset followed by alpha-beta (7-30 Hz) desynchronization. This activity was strongest in occipito-parietal areas for visual perturbations and strongest in sensorimotor and supplementary motor areas for pull perturbations. Greater tibialis anterior and peroneus longus EMG activity occurred during pull perturbations compared to visual perturbations. Connectivity results were sparser than expected, with significant theta connectivity from anterior cingulate to right sensorimotor area in all conditions.

Discussion. As hypothesized, occipito-parietal theta-alpha synchronization was stronger for visual perturbations and supplementary motor theta-alpha synchronization was stronger for pull perturbations. Similar synchronization activity has been seen in EEG and subthalamic nucleus recordings during conflict [7]. The robustness of this activity pattern across multiple cortical areas suggest this time-frequency activity may be a useful cognitive biomarker for balance control assessment. We found less cortical connectivity than expected, which may reflect a lack of significantly different baseline connectivity compared to perturbation-evoked connectivity [8]. Such source-localized measures could be useful to future mobile brain and body imaging studies for assessing cognitive activity in older adults during balance control.

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ID: 111 / **Poster: 53**
Poster Submissions
Topics: Mobile Brain/Body Imaging, NIRS, Gait- and Gait Rehabilitation
Keywords: locomotion, fNIRS, motor control

Evaluating the assessment of cortical hemodynamics in dual-task walking

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Background. Functional near-infrared spectroscopy (fNIRS) is a promising technique to assess cortical activity. In the field of human movement sciences, the crucial advantage of fNIRS over other techniques is that cortical activity can robustly be measured in moving subjects, e.g. walking (Hamacher, Herold, Wiegel, Hamacher, & Schega, 2015; Herold et al., 2017). This is of clinical significance, because an increase in cortical activity during dual-task walking is a valid predictor of falls in older individuals (Verghese, Wang, Ayers, Izzetoglu, & Holtzer, 2017). Therefore, fNIRS signals derived from walking subjects could be capable markers to evaluate gait performance e.g. to gauge the success of gait rehabilitation interventions (Clark, 2015). The current study addresses the data acquisition of dual-task walking time series using fNIRS. Hereby, we aim to clarify (i) for the first time how reliable the fNIRS test procedure is and (ii) if it can distinguish between older and young cohorts.

Method. In 25 young (age 24 ± 5) and 13 older (age 71 ± 8) individuals, the cortical activation (Prefrontal Cortex, PFC; Premotor Cortex, PMC; Supplementary Motor Area, SMA) during dual-task walking was assessed (NIRSport, NIRx, Berlin, Germany). After a test-retest interval of 7 days, the older subjects were re-measured. The test-retest reliability was calculated with intraclass correlation coefficients (ICC), the Bias and Limits of Agreement and the standard errors of the mean. Additionally, we checked whether the data of young and older participants were significant different using paired t-tests.

Results. ICC values displayed poor to excellent reliability. In general, the data derived from the PFC showed lower ICC-values than in the PMC or in the SMA. Furthermore, we found significant differences between young and older participants regarding the relative changes of the oxygenated haemoglobin in SMA and PMC.

Discussion. The current study provides the first reliability data of fNIRS signals derived from dual-task gait. Our fNIRS data indicate that we are able to distinguish between older and young individuals walking with a cognitive dual task. Methodological issues regarding the reliability of assessing PFC oxygenation should urgently be resolved in future studies.

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ID: 112 / Poster: 47
Poster Submissions
Topics: Mobile EEG, Mobile Brain/Body Imaging, Analyses Tools, EEG, Sports- and Movement Sciences, Cognition and Motor Function
Keywords: electroencephalography, postural control, dual-task, sensorimotor control, cortical activation

Effect of a cognitive dual-task on electrocortical activation during single leg stance

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Background. Examining postural sway with a concurrent dual-task under experimental conditions, a U-shaped interaction between postural control and cognitive demands was observed resulting in either facilitations or impairments of performance [1-3]. Various electroencephalography (EEG) studies reveal that frontal, central and parietal parts of the cortex seem to be involved in static postural control as well as dual tasking [4-5]. However, cortical mechanisms beyond facilitation and impairment of postural sway have not been examined. The aim of the present study was to investigate underlying cortical mechanisms that contribute to modulations of postural sway under dual-task conditions.

Method. Eleven healthy male university students were examined. Postural sway and cortical activation were recorded simultaneously using a triaxial forceplate (FP6090-15, Bertec, USA, FP) and a mobile 128 channel EEG system using active electrodes (BrainProducts, Germany). Subjects were asked to perform single leg stances (SLS) and SLS with concurrent counting backwards task (SLD). FP data was processed to calculate area of sway. EEG data was analysed using independent component analysis to decompose independent components (ICs) of brain activity. Brain Ics were cluster-analyzed and paired sampled t-tests ($p<.05$) were applied to analyse differences between SLS and SLD for theta (5 to <8 Hz) alpha-1 (8 to <10 Hz) and alpha-2 power (10 to <12 Hz).

Results. Force plate data revealed that the area of sway slightly decreased, but did not change significantly from SLS to SLD. The EEG analysis revealed seven clusters of functional brain ICs (midline frontal, left-frontal, left motor, midline motor, left parietal, midline parietal). Significant differences between SLS and SLD were observed for all analyzed frequency bands. The main findings were significant increases of theta power in frontal clusters and increases of alpha-1 and alpha-2 activity in central and parietal clusters from SLS to SLD.

Discussion. The observed increases in frontal theta activity may indicate increased memory load induced by the counting backwards task [6]. Additionally, the present increases in alpha activity are discussed to be associated with reduced cortical alertness and processing [7]. Hence, reductions of activity in central and parietal brain areas may support hypotheses of automation of postural control that might explain facilitation [2]. EEG assessments in dual-task paradigms seem applicable and reveal a more physiological insight into postural control than classical experimental designs. Prospectively, mobile EEG assessment during postural control might be a tool to quantify automation processes in special populations, e.g. elderly or after musculoskeletal injuries [8]. Further research is needed to support these findings.

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ID: 113 / Poster: 18
Poster Submissions
Topics: Mobile EEG, Mobile Brain/Body Imaging, EEG, Sports- and Movement Sciences
Keywords: mobile EEG, brain connectivity, phase lag index, postural control, single leg stance

Exploring Functional Brain Connectivity of Postural Control in Upright Stance

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Background. Postural control as a crucial determinant for functional movements reflects a multimodal interaction of the sensorimotor system, incorporating the processing of somatosensory, vestibular and visual information in the central nervous system [1]. Findings from electroencephalographic (EEG) investigations suggest that prefrontal, motor and parietal areas of the cortex contribute to postural control of human upright stance in response to naturally-occurring postural sway and postural perturbations [2], as indicated by increased theta [2] and decreased alpha-[2,3] activity. Although recent findings have already provided initial insights into cortical activity during postural control [4,5,6], the underlying functional brain networks remain uncertain. Therefore, the aim of the present study was to explore functional connectivity as a measure of brain networks between prefrontal, motor and parietal cortical areas in human upright stance.

Methods. Cortical activity during bipedal and single leg stance was investigated in 12 healthy subjects using 128 active EEG electrodes (ActiCap, BrainProducts, Germany), while standing on a triaxial force plate (FP6090-15, Bertec, USA). The EEG signals were divided into twelve 4-seconds epochs of 512 samples for each subject and condition [7]. For further analysis, six regions of interest (ROIs) were built for bi-hemispheric (L/R) frontal (fL, fR), motor (mL, mR) and parietal areas (pL, pR) of the cortex. After an independent component analysis based artefact rejection, estimations of the phase lag index (PLI) were conducted as a measure of functional connectivity [8]. For statistical comparisons between bipedal and single leg stance, the mean PLI was calculated in theta and alpha-2 frequency bands by averaging PLIs among all possible channel pairs within and between ROIs. Postural control was analyzed by area of sway and sway velocity. Paired t-tests were applied to EEG and force plate data in order to test for statistical differences between conditions.

Results. The present results demonstrated a significantly increased area of sway in single leg compared to bipedal stance ($p < 0.001$). Functional connectivity decreased from bipedal to single leg stance and showed significantly lower PLIs in the alpha-2 frequency band for inter hemispherical pairs of motor and parietal areas (mL ó mR, $p = 0.024$; mL ó pR, $p = 0.021$; mR ó pL, $p = 0.034$), as well as for fL ó pR ($p = 0.044$) and fR ó cL ($p = 0.005$). Furthermore, the PLI significantly decreased in the theta band for mL ó pR ($p = 0.044$).

Discussion. These findings provide new insights into functional brain networks underlying postural control. Although the PLI has predominantly been applied to EEG resting state data, this method seems to be equally applicable to data derived from static human stance. Decreased inter-hemispherical functional connectivity of motor and sensory areas may point to focused task-specific sensorimotor processing of the brain, with adaptations of cortical contributions to postural control while standing on one leg [4,9]. However, further studies are needed to help understand brain and body dynamics related to postural control.

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ID: 114 / **Poster: 9**
Poster Submissions
Topics: Mobile EEG, Mobile Brain/Body Imaging, EEG, Cognition and Motor Function
Keywords: EEG, VWM, Cognition, Exercise, Aerobic

EEG evidence for improved visual working memory performance during standing and exercise

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Background. While a substantial body of research has investigated the effects of aerobic exercise on cognitive performance, few have monitored exercise-concurrent cognitive processes via electroencephalography (EEG), and fewer still using an event-related potential (ERP) approach. As such, little is known regarding how the temporal dynamics of cognitive processing are influenced during aerobic activity. Here, we aimed to elucidate what influence aerobic exercise and upright posture might have on the temporal dynamics of concurrent visual working memory (VWM) performance.

Methods. Eighteen participants performed a VWM retro-cue task during conditions of both rest and acute aerobic exercise across two postural modalities: while seated (using a stationary bicycle) and standing upright (using a treadmill). EEG was recorded throughout the experimental conditions using a 64-channel mobile EEG system (Brain Products ActiCAP, MOVE, Munich, Germany). Independent component analysis (ICA) was performed to identify and remove components representing blinks and saccades, as well components related to movement showing clearly identifiable patterns (e.g., step frequencies). Following this, three consecutive phases of the VWM processing pipeline representable via lateralized ERPs were assessed – access to VWM representations (CDA), response selection (sLRP), and response execution (rLRP).

Results. *Behavioural data.* Reaction times (RTs) were found to be expediated during exercise, while both RTs and error rates (ERs) were markedly decreased during upright posture.
Delayed VWM access during upright posture. No effects of exercise were observed in relation to the CDA timing. However, a main effect of body posture was observed, where CDA onset occurred significantly later in upright as compared to seated conditions.
Speeded motor-response decisions during exercise and standing. Analysis of the sLRP timing showed a similar pattern to RTs, where sLRP onset occurred significantly earlier in active and upright conditions. The onset of rLRP, by contrast, did not demonstrate any differences between conditions.

Discussion. Acute aerobic exercise and upright body posture can have faciliatory effects on VWM task performance. Within an optimal range of cardiovascular load, aerobic exercise can significantly improve processing speed, while upright posture can enhance both processing speed and response accuracy. Interestingly, VWM performance was found to be lowest in resting, seated conditions - the physiological state in which nearly all other neuro-cognitive research is conducted. Analysis of ERL waves isolated speed of processing facilitations to a finite temporospatial stage of the cognitive processing pipeline, providing a clear indication of when, and some suggestion as to where the neural origins of the observed effect took place. The present study is unique in these findings, as to the best of our knowledge no prior research has attempted to disentangle the temporal dynamics of exercise concurrent VWM performance using a staged

ERL approach. As such, this study provides an ample theoretical and methodological basis to inform future investigations of visual cognition during exercise.

ID: 115 / **Poster: 33**
Poster Submissions
Topics: Mobile EEG, Mobile Brain/Body Imaging, Analyses Tools, EEG
Keywords: Automatic Sleep-Staging, Bayesian Statistics, Two-Channel EEG

Higher-Order Viterbi Algorithm for Automatic Two-Channel Sleep-Staging

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Background. Recent attempts have been made to automatize the classification of polysomno-graphic sleep data into sleep stages as defined as described by the American Association of Sleep Medicines Scoring Manual, as this would lessen the overhead associated with sleep diagnosis. In the mentioned manual, 30-second blocks of polysomnographic measurements are classified as one of five conditions: Awake, Light Sleep (N1, N2), Deep Sleep (N3) and REM sleep. In order to further facilitate the sleep measurement itself, we would like to automatize the scoring process while relying only on two channels of measurements, namely the mastoidal electrodes, which are easily accessible for portable EEG systems.

Method. The underlying model for the automatic sleep-staging is a hidden Markov Model, where the sleep stages are viewed as nodes of a Markov chain. The first step is the reduction of the dimensionality of the data, while simultaneously considering the frequency domain. This is done using mel-frequency cepstral coeffcients. Afterwards, we use a higher-order (order 2) Viterbi algorithm, in iterative procedure to find the most likely chain of sleep stages given the data. The method was tested in a dataset of n = 8 patients (healthy subjects, mean age _ SD = 39_8:1 , five females), where the first half of the night was used as a training set and the second half of the night was used as a test set. The classification was then compared to the classification of a certified polysomnographic technician, who used a polysomnography as underlying information.

Result. When comparing the classification of the algorithm with the trained technician, there was an averaged error rate of 24%. The result for Cohens, when averaged over the 8 test subjects, was 0.6489.

Discussion. Since the interrater variability for sleep-scoring is quite high (with consensus only on around 82% of the dataset), the presented results show a promising possibility for further research. Even though the information given for the automatic sleep-staging was drastically reduced in comparison to the sleep-scoring of the technician, who used a full polysomnography, the overall agreement of the sleep classification is quite high. We would like to extend this research using more data and different methods of Bayesian statistics.

ID: 116 / **Poster: 34**
Poster Submissions
Topics: Mobile EEG, Analyses Tools, EEG, Therapeutic Intervention, Cognition and Motor Function
Keywords: EEG, Sleep, Creativity, Robotics, Dream

Dormio: Interfacing with Dreams

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Background. Current technological interfaces miss out on an opportunity to access information from the unique cognition ongoing during dreams. Sleep offers an opportunity for prompting creative thought in the absence of directed attention, if only dreams can be controlled. During sleep onset, a window of opportunity arises in the form of Hypnagogia, a semi-lucid sleep state where we all begin dreaming before we fall fully unconscious. Hypnagogia is characterized by phenomenological unpredictability and spontaneous, fluid idea association. Edison, Tesla, Poe, and Dalí each accessed this state by napping with a steel ball in hand to capture creative ideas generated in hypnagogic microdreams when it dropped to the floor below. We present Dormio, an interface to augment human creativity by interacting with users in Hypnagogia. Using a social robot, a muscular sleep stage tracking system and EEG/audio data capture, we are able to influence, extract information from, and extend hypnagogic microdreams for the first time.

Methods. The Dormio system used consists of a Muse EEG and a hand-position sensitive glove. Participants wearing the Dormio system were instructed by the Jibo social robot to fall asleep. They were prompted to think of a word (either “Rabbit” or “Fork”) and asked to focus on any ideas or images that came to mind. Once either a loss of muscle control or presence of an EEG sleep spindle was picked up by the system, signaling an end to hypnagogia and transition into deeper sleep, the robot alerted participants they were falling asleep and prompted them with the test word again, incepting this content into their dream. Participants were fully awoken after 3 rounds of prompting and tested on creativity related to these words, as compared to an awake-prompted control group.

Results. 5/6 of participants showed increased levels of creativity as measured by elaboration, originality, fluency and flexibility on the Alternative Uses Task. 4/6 said ideas encountered in Hypnagogia were creative. Time voluntarily spent on creative content generation increased by an average of 158 seconds in Hypnagogia vs Control groups. Subject's report on the experience is also informative: “I stepped out of myself. Ideas were not coming from me, they were just passing through my head. I could be reflective and sort of coherent while also being in this state of I’m not really here...I really wanted to do it again...it was very similar to when if I’m meditating, this sense of not really being in the room. I felt I was nowhere really, in this kind of nowhere space where all these ideas exist”

Discussion. The Dormio system demonstrates the feasibility of research on sleep in mobile settings with cheap, comfortable wearable sensors. This project demonstrates a first use case for technological interfacing with sleep, namely augmenting creativity via Hypnagogia interfacing. More broadly, it enables future research into sleep without relying on the typical cost-prohibitive, cumbersome, tethered sleep neuroscience research systems.

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ID: 117 / **Poster: 44**
Poster Submissions
Topics: Mobile EEG, Mobile Brain/Body Imaging, Analyses Tools, EEG
Keywords: light, visitor experience, museums, lighting conditions

Studying the effect of light on the experience of space in situ: towards a novel and interdisciplinary methodological framework

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Background. In this paper, we propose a novel methodological framework for *in situ* studies of lighting experience, combining psychophysiological measures with behavioural observations and qualitative insights. Recent discoveries in circadian research demonstrate the multifaceted effect of light on humans yielding psychological and physiological, non-visual responses associated with circadian effects. These effects are manifested as conscious emotions and cognitive processes or even as unconscious states and behaviours. In addition, visual and non-visual effects of the light stimulus are part of a diffuse, multisensory environment, therefore, experience in space is a result of the combined effect of different sensory modalities. The complexity of the human-light interaction reflects on the growing number of studies on the subject originating from different research domains and discourses, such as neuroscience, psychology, marketing, architecture and lighting science. However, many studies solely focus on a single aspect of light's influence on humans and only few are performed *in situ*, in the multisensory real-world, instead of the highly controlled laboratory environment. And yet, *in situ* studies are extremely useful if the research findings are meant to apply in real world and inform real practice. Therefore, there is a clear need for developing interdisciplinary collaborative methodological frameworks, extending on current research practices. Interdisciplinary *in situ* research is now being enabled by technological advances on psychophysiological monitoring, that have allowed for the production of relatively low cost mobile equipment. To understand light in the context of space user relationship, as dictated by the need for interdisciplinary approaches in lighting research accounting for all psychological and biological, conscious and unconscious effects of light, we propose a novel methodological framework for *in situ* studies, to document both visual and non-visual responses in museum environments. Our framework combines psychophysiological measures and behavioural observations, and qualitative insights. For our research project, we use novel technologies such as mobile Electroencephalography (EEG) and Electrodermal Activity (EDA / GSR) combined with systematic observations of participant behaviours, as well as with self-reported measures from structured questionnaires or semi-structured interviews. Although the space of focus is that of museums, the methodology can be widely applied in lighting research in retail, leisure and tourism spaces, urban landscapes and other short stay spaces.

Methods. To study the effect of light on visitor experience, we select the Parthenon Gallery of the Acropolis Museum as a case study. The Parthenon Gallery of the Acropolis Museum, being daylit, offers a great palette of temporally and spatially dependable lighting effects as the lighting condition vary dynamically over the course of the day, wing of the gallery and the change of seasons. We select three lighting conditions to perform visits, during midday, evening (half an hour before sunset) and night. A total of 60 recruited paid male and female participants, split in three groups visit the Parthenon Gallery in one of the three selected lighting conditions. The apparatus is consisted of a mobile 14 channel Electroencephalography (EEG) head cap, a electrodermal activity (EDA) tracking wristband and a miniature camera. EEG electrodes are positioned according to the international 10-20 system at AF3, F7, F3, FC5, T7, P7, O1, O2, P8, T8, FC6, F4, F8 and AF4. Sampling rate of the EEG amplifier is 128Hz and of the EDA wristband is 4Hz. Each participant visits the Parthenon Gallery alone, wearing the EEG headcap and EDA wristband, while followed by the researcher wearing the miniature camera documenting overt behaviour. Following the completion of the visit, the participant takes part in a semi-structured interview in the space of the Parthenon Gallery and completes a questionnaire of the Russel and Pratt scale for environmental appraisal. Overt behaviour is analysed to document interaction of visitors with the exhibits and time allocation. We connote “engagement”, the state, when a visitor ‘plants the feet’, stops and looks at an exhibit, or significantly slows her walking pace. When “engagement” is combined with a phasic skin coductance responses, we register an “interaction”. With the means of comparative Analysis, we compare number of “interactions” per wing (each wing has different lighting conditions) and time of visit. Comparisons of average tonic skin conductance levels, as well as the visit duration per wing are also drawn and cartographically demonstrated. EEG measures, such as the relative power in different frequency bands, are also suggestive of visitor experience. Increate power in the frontal beta frequency band suggests a state of alertness, while alpha frequency band can be used to assess the valence of visitors’ emotion. We also analyse the verbalisation of the experience, as an indicator of thought processes and to complement our physiological data. For instance, although phasic SCR responses indicate arousal, however it is unclear whether this manifest a positive (attention, excitement) or negative (stress, fear) response.

Results. While this study is still on-going, initial analysis of self-reported and behavioural data suggests that there is a clear relationship between emotional experience, attention and time allocation with lighting conditions. In our study, we observe two types of behaviours: a “habitual” and a genuinely engaged behaviour. In the first case, visitors, stop and look at exhibits, however they fail to stimulate or maintain their interest. In the second scenario, visitors are intrigued cognitively and emotionally, and excited.

Conclusions. Observing over behaviour, for instance, where people stop and plant their feet, or allocate their time, has been extensively used in visitor studies. However, here we demonstrate that there is another aspect of experience contained within observed behaviour that could provide insights in the conscious and unconscious processes that define the experience in space. Those insights are provided by event related physiological parameters such as phasic EDA or overall indicators of cognitive state such as alpha and beta EEG waves. Taking research out of the laboratory and to the real world, using new tools, requires, new experimental designs, methods and techniques. However, any new methodological frameworks ought to draw on the vast and existing research and developed methodologies, in order to explore new opportunities for understanding the elusive affair of experience in space.

ID: 118 / **Poster: 48**
Poster Submissions
Topics: Mobile EEG, Neuroergonomics
Keywords: spatial learning, incidental learning, navigation assistance systems, landmark

Navigation instructions including landmark information increase incidental spatial learning

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Background. Navigation assistance systems support the user while navigating through an environment. With an increasing use of navigation assistance systems, however, orienting abilities decrease as less information about the spatial surrounding is processed (Münzer et al., 2006). Landmarks are important for the acquisition of spatial knowledge. Here, we present data of a research approach aiming at spatial knowledge acquisition by including landmark information in navigation instructions.

Method. Navigation instructions were modified in four different experiments and were always compared to standard navigation instructions. Modified navigation instructions provided the landmark name and landmark specific information at four different levels: no (named as short condition), redundant (contrast), additional (long) or participant related (personal-reference). The experiments comprised simulated driving through a virtual city (Exp. I: Gramann et al., 2017 & Exp. II: Wunderlich & Gramann, 2018), watching an interactive first-person perspective video of a walk through Berlin (Exp. III) and actively walking the identical route through Berlin (Exp. IV). In all experiments participants had to answer spatial tasks testing their acquired knowledge about the previous navigated environment. In the driving simulator, participants followed a predefined route through an unknown virtual city and had to solve spatial tasks immediately afterwards (Exp. I) or three weeks later (Exp. II). The interactive video setup (Exp. III) allowed brain activity analysis of the spatial knowledge acquisition under lab conditions while using realistic stimulus material. Spatial knowledge was tested immediately after the navigation session. To test the impact of kinesthetic and proprioceptive information during navigation on the acquired spatial knowledge, Exp. IV investigated pedestrians navigating through Berlin wearing mobile EEG with immediate knowledge assessment after navigation.

Results. None of the experiments showed an increase of mental load during the use of modified navigation instructions compared to the control group. The recognition performance immediately afterwards and after three weeks revealed an improved spatial knowledge for modified navigation instructions without differences between different modifications. Accompanying event-related brain activity presented significantly higher amplitudes of the late positive complex for modified navigation instruction conditions without impact of different landmark types. Blink rate and blink-based event-related brain activity during the navigation phase in Exp. IV revealed differences in visual information processing in the navigation instruction conditions.

Discussion. Providing landmark information improved incidental spatial learning without increasing mental load. This improvement was evident for short and long-term memory. Event-related brain activity during landmark recognition differed between navigation instructions, but was independent of landmark types, reflecting generally altered information retrieval with modified navigation assistance. Blink-based analysis of EEG activity during real-world navigation demonstrated differences in information processing dependent on navigation instructions already during navigation. In conclusion, landmark information in navigation instructions is a promising step towards navigation assistance systems that incidentally train the users' spatial abilities without increasing mental load.

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ID: 119 / **Poster: 22**
Poster Submissions
Topics: Mobile EEG, Mobile Brain/Body Imaging, Gait- and Gait Rehabilitation
Keywords: EEG, gait, cerebral palsy

Cortical Network Activity during Walking is Altered in Children with Unilateral Cerebral Palsy as Revealed by EEG

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Background. Portable neuroimaging enables the study of brain activity during movements, such as walking, and in study populations, such as children with movement disorders, which would not be feasible with traditional techniques. Previous studies in healthy adults have implicated μ (8-13 Hz) and β (13-30 Hz) rhythms, which are established neural correlates of sensorimotor activity [1], in motor control of steady walking [2] and in gait adaptations of speed and step length [3,4]. EEG has not yet been utilized to examine potential alterations in these rhythms and their role in walking in children with brain injury.

Methods. Ten children with unilateral cerebral palsy (CP) (age: 14.9±3.8 years) and 10 age- and gender-matched typically developing (TD) controls (age: 14.9±3.2 years) participated in the IRB-approved study after informed consent. 64-channel wireless active EEG placed according to the 10-20 system was recorded during standing rest (~2 mins) and treadmill walking (~5 mins) sampled at 1000 Hz. Kinematic data synchronized with EEG tracked gait events to epoch EEG. EEG signals were processed using a previously developed pipeline, including independent component analysis, to mitigate gait-related artifact [3]. Outcome measures included the log-ratio of power during walking to rest, i.e., task related power (TRP) in the sensorimotor region and intra- and inter-hemispheric task related coherence (TRC) in the μ and β bands. Two-sample t-tests ($p<0.05$) were used to evaluate statistical differences between groups.

Results. Sensorimotor μ and β mean TRP was negative for both hemispheres, with no statistical difference ($p>0.05$) between TD and CP groups, indicating that task-related desynchronization was present during treadmill walking compared to standing. Intra-hemispheric μ band TRC between sensorimotor and prefrontal regions was significantly increased in the dominant hemisphere ($p=0.015$) in the CP cohort compared to TD, with a trend for increased TRC in the nondominant hemisphere ($p=0.079$). No other significant differences between groups were identified for intra- or inter-hemispheric TRC.

Discussion. Similar to adults, children with TD and CP exhibited task related sensorimotor desynchronization in μ and β bands during walking. The absence of hemispheric TRP differences in our CP cohort with unilateral brain injuries was surprising, but may be explained by the group's high functional level (GMFCS I/II); hemispheric differences may exist in less functional individuals. Yet, elevated motor-frontal intra-hemispheric coherence suggests the motor cortical network may be altered in CP compared TD, a result in line with previous work [5]. Finally, our results show that EEG can detect differences in cortical activity between those with and without brain injury. Interpreting these differences in combination with individual-specific movement alterations may elucidate neural mechanisms underlying the consequent motor limitations.

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ID: 120 / **Poster: 1**
Poster Submissions
Topics: Mobile EEG, Mobile Brain/Body Imaging, Therapeutic Intervention
Keywords: EEG Hyperscanning, Brain/Body Imaging, Psychotherapy, Functional Connectivity, Motion Energy Analysis

Towards Obtaining Longitudinal Brain/Body Functional Connectivity in Semi-Structured Natural Interaction Settings: A Preliminary Analysis

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Background. Understanding behaviorally relevant brain function will ultimately depend on our comprehension of large-scale (neuro)physiological dynamics in action within geographical and socio-cultural niches [1]. Reaching this goal will depend on building mathematical objects –observable and measurable– at both epistemological and methodological levels [1]. Taking into account that “the world” is most often composed by conspecifics, social interaction is a crucial dimension of healthy behavior. However, interaction research in natural settings is difficult at best [2,3]. This is why, as a point in-between structured laboratory settings and completely natural behavior, we have suggested exploring ‘semi-structured settings [1], and within these, psychotherapy as a good case allowing the study of dyadic interaction [4], without having a profound theoretical framework [1]. Importantly, evidence concerning verbal, nonverbal, and neural coordination as predictors of therapeutic alliance and outcome in psychotherapy grows exponentially [4-7]. Here we try -for the first time- to integrate the long tradition of psychotherapeutic processes research with advanced brain/body signal processing.

Methods. We acquired multiple data sources from a real psychotherapeutic setting. The dataset used in the present work consisted in EEG and body movement data from both patient and therapist obtained from 17 1-hour-sessions taken from the first half of the complete 67-session long full psychotherapy. EEG was recorded at 128 Hz and bandpassed 0.2-45 Hz acquired from two 14-channel Emotiv EPOC headsets[8,9]. Audiovisual streams were recorded using two high-definition digital video cameras. The patient was a 48-year old divorced female, scoring 36 BDI-I10. and 103 OQ11. points at beginning of treatment. The therapist was a 53-year old male with extensive experience as a psychoanalytic psychotherapist. Both therapist and patient gave explicit written consent and the data collection procedures were approved by local ethics committee. Video and audio data were offline coded by two independent coders using ELAN12. into “change” [13] and “rupture” [14] episodes. Body movement data was analyzed using the Motion Energy Analysis (MEA) algorithm [5]. Coded episodes were synchronized with EEG recordings, allowing us to generate “change” and “rupture” EEG epochs with corresponding body movement data. EEG epochs were visually inspected for manual rejection of non-linear artifacts in order to proceed with ICA-based cleaning routines[15]. Artifact-free data were mined using ICA[16]. Robust independent components (rIC) were extracted per session by running ICA 100 times and then using the most highly correlated components across all runs as described in [17]. Together, rIC and MEA time-series were used to compute *de-biased weighted phase-lag index* (dwPLI) [18] in order to quantify:
a) Inter-participant brain-brain synchronization as modelled by rIC
b) Inter-participant body-body synchronization as modelled by MEA

c) Intra-participant brain-body synchronization as modelled by rIC and MEA
The analysis pipeline is described in Figure 1. MEA analysis was carried out using the MEA software[5]. All other analyses were performed using MATLAB R2016b (The MathWorks, Natick, MA).

Results. We compare “change” vs “rupture” episodes at the intra- and inter-participant levels. Together, our measures (a,b,c) quantify intra- and inter-participant brain/body synchronization dynamics in the context of human interaction. Our results describe the functional connectivity patterns as they change longitudinally throughout the first half of the psychotherapeutic setting in different *regulation* episodes (i.e. change vs rupture). Results are presented for the patient and therapist comparing “change” against “rupture” episodes, longitudinally (Figure 2).

Discussion
Our work describes, for the first time, longitudinal brain/body static functional connectivity patterns obtained from an ecological semi-structured interactional setting [1]. So far, it seems that our rIC-based dwPLI seem to provide an efficient measure of interactional coupling within the alpha range (8-15 Hz - bottom panel Figure 2A), in contrast MEA-based dwPLI does not seem to capture the interaction between patient and therapist (bottom panel Figure 2B). Static brain/body functional connectomes are different for both patient and therapist. The preliminary results of this novel approach to multi-participant brain/body imaging provides insights on the functional dynamics of human coordinated interaction in the context of psychotherapy.

ID: 121 / Poster: 51
Poster Submissions
Topics: Mobile EEG, Mobile Brain/Body Imaging, EEG
Keywords: Parkinson's Disease, Event Related Potentials

Getting Ready To Freeze: Neurophysiological Correlates of Decision Making, Response Inhibition and Motor Preparation While Stepping in Parkinson's Disease Patients With and Without Freezing of Gait

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Background. To investigate behavioural and electrophysiological markers of motor preparation, executive function and response execution in People with Parkinson's disease (PwP) with and without freezing of gait (FOG) while sitting (single-task) and stepping (dualtask). FOG pathophysiology is poorly understood but is associated with motor preparation and executive deficits. We examine behavioural and event related responses (ERPs) for simple target motor response task in PwP with and without FOG and the impact of locomotion [1-7].

Methods. Behavioural and EEG data were acquired from 20 PD patients (10 with FOG) while they performed a two-stimulus oddball task while sitting or stepping in place [8,9]. The EEG data was transformed to current source density (CSD) to tease apart and investigate cortical markers of response conflict (N2), cognitive decision making (P3b or centroparietal positivity, CPP) and motor readiness potential (the lateralized readiness potential, LRP) [6,10].

Results. Response times (RT) while stepping were significantly slower than while seated for the patients with freezing. However, RTs were *faster* while stepping for the non-freezers [9]. In both conditions, there was no difference in the P3 response between groups but there were differences in the motor readiness potential onset which was more pronounced in the stepping condition. Furthermore in the freezing group there was a reduction in response inhibition marker (N2) prior in the stepping condition

Conclusions: This study confirms, in an ecological setting, that markers of response inhibition and motor preparation, rather than cognitive decision-making potentials differentiate freezers and non-freezers. The faster stepping RTs in the non-freezers suggests they recruit more motor resources to perform a dual-task [11,12]. The slower stepping RTs suggests the freezers are unable to do this. This may be the result of differences in cognitive reserve in freezers and non-freezers. When stress is placed on these cognitive resources, deterioration in task performance becomes clinically detectable in freezers. This suggests a maladaptive system which is prone to overload in stressful situations, which could result in motor breakdown and freezing of gait.

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ID: 122 / Poster: 4
Poster Submissions
Topics: EEG, Neuroergonomics
Keywords: spectral analysis, FFT, theta, alpha

Maximizing task-variance in spectral parameters of the ongoing EEG by pink noise removal

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Background. The experimental investigation of complex cognitive phenomena often faces the problem that it may not be appropriate to transfer findings of controlled laboratory experiments to real-life scenarios. While the external validity of laboratory findings with regard to basic cognitive processes might still be given, lab specific task-characteristics like a minimized sensory input, a highly repetitive nature or an external pacing of the task could render lab and real-life settings not comparable when investigating high-level constructs. Mobile EEG allows for the assessment of cognitive processes in order to investigate high-level constructs like motivation or mental fatigue in settings with a high ecological validity. Many EEG analyses rely on event related measures to infer on task-related cognitive mechanisms. In real-life scenarios, however, distinct events do not exist and artificially adding events to a task in order to probe for cognitive processes would cause interference.

Methods. Assessing cognitive states and cognitive processing in the EEG without distinct events may be realized by analyzing the spectral properties of the ongoing EEG. While these measures proved to be sufficiently responsive to allow for fine-grained analysis, the possibilities to map spectral power modulations to mental states are still limited. One reason for this is that power modulations in different frequency bands do not occur independently, another being that task-related modulations of the spectrogram add to the 1/f shaped neural background noise of the EEG. Relative power measures might be suited to improve the signal to noise ratio in the parameterized EEG, but are nevertheless still subject to cross-frequency dependencies. We developed and tested a curve-fitting approach, capable of capturing task-specific modulations of the spectrogram, thus maximizing task-variance in the parameterized EEG.

Results / Discussion. The application of our curve fitting technique to driving simulator data indicated that this approach could indeed be suited to improve the signal to noise ratio when analyzing the ongoing EEG.

ID: 123 / Poster: 35
Poster Submissions
Topics: EEG, Sports- and Movement Sciences, Cognition and Motor Function
Keywords: haptic interfaces, motor imagery, ERD/ERS, EEG

Measuring kinesthetic motor imagery using haptic interface and EEG registration. A novel paradigm

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Background. Motor imagery is defined as the mental execution of a movement without any real action [1] and may be subdivided into visual-motor imagery (VMI) and kinesthetic imagery (KMI). If there is no specific instruction given, the subject may imagine seeing himself or another person performing an action (exterior view from the third-person perspective) or a self-performed action that is accompanied by a feeling of actually performing the task (kinesthetic experience from the firstperson perspective)[2]. Some studies suggest that using the kinesthetic motor imagery strategies may be more beneficial than visual in therapeutic and sports applications [3]. However, in most cases, particular motor imagery perspective is activated only by instructions explicitly given to subjects. The classic paradigms for motor imagery involve simple hand or finger movements, without any measure of its accuracy [4]. It is therefore difficult to determine whether subjects were biased towards using one type of strategy or the other. Our goal was to create and evaluate a novel motor imagery paradigm which provides a more direct and objective measure of KMI performance and is suitable for testing with psychophysiological techniques using the Mobile Brain/Body imaging (MoBI) environment [5]. We have designed a task of comparing different kinesthetic stimuli generated by the 1-DoF (degree of freedom) haptic interface (Fig. 1A) requiring an involvement of motor imagery. As an external measure of validity, we have used the correctness of responses and event-related desynchronization (ERD) of EEG signal recorded during imagery of right and left-hand movement.

Method: During the experiment the participants were given following instruction: (1) squeeze the handle of the haptic interface by right or left hand and memorize the force that was applied to this movement, (2) repeat this action for another stimulus, (3) relax, (4) recall one of the previous stimuli (depending on visual cue), (5) squeeze the handle again and compare this kinesthetic experience with the previous one, (6) answer the question: ”Is this stimulus the same as the previous one?”. The EEG data were registered during rest (Baseline) and recall (KMI task) conditions (Fig. 1B-C). Each subject performed a total of 320 trials (160 trials each for imagined left and right-hand movement). The event-related spectral perturbation (ERSP) method 6. was used to analyze sensorimotor rhythms (SMR) variation among experimental conditions.

Results. The ERD during KMI task was significantly higher in terms of SMR power suppression (dB) on the channels located contralaterally to the hand movements. The difference between conditions was greatest in the left central-parietal area (CP3) and alpha (8-13 Hz) and beta (14-30 Hz) bands (Fig. 2).

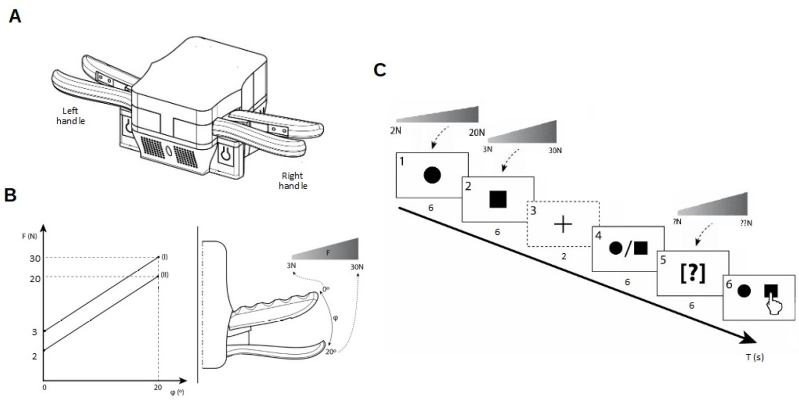

Fig. 2. The averaged time-frequency maps on CP3 under KMI tasks. The dotted-line was marked at the onset of task, the blue color indicates the ERD phenomenon.

Discussion Our results demonstrated that the procedure of comparing stimuli generated by the haptic interface evokes an SMR-ERD pattern typical for imagery of movement. This could be a promising approach to rehabilitate patients with motor disabilities, user-training in brain computer-interfaces and sports applications.

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ID: 124 / **Poster: 23**
Poster Submissions
Topics: Mobile EEG, Analyses Tools, EEG, Synchronization
Keywords: hyperscanning, real-world neuroscience, EEG, brain synchrony, social interaction

Learning and connecting in the real world: conducting neuroscience research in high school classrooms and museums

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Background. Laboratory research has produced tremendous insight into how the human brain supports social interaction and learning. Still, laboratory-generated findings do not always straightforwardly generalize to real-world environments [1]. We conducted a series of experiments in schools and museums in an effort to bridge the neuroscience laboratory and naturalistic social settings. In one set of studies, we collaborated with New York City high schools to collect electroencephalogram (EEG) data from students as they engaged in natural classroom interactions [2-4]. In related work, we recorded hyperscanning EEG from thousands of museum visitors as they freely engaged in face-to-face interaction for 10 minutes [5].

Methods. We used the EMOTIV EPOC EEG headset with custom software (openFrameworks) to record hyperscanning EEG from two groups of 12 students and their teacher during their regular senior biology classes (17 early morning, mid-morning and afternoon classes total; content was taught via lectures and videos). Brain synchrony between pairs of students was quantified for each 1-sec epoch: for each teaching block and each student-student pair, inter-subject coherence was computed for 2.5 Hz bins (1-20Hz) then averaged across electrodes, frequencies, student pairs (per student), and epochs, resulting in one synchrony value for each student for each class activity on each day. Mean occipital alpha power (centered around each student's individual alpha peak) was computed for each student/day/class activity as a neural proxy for student attentiveness [6]. For the museum study, projected power correlations [7] and imaginary coherence [8] were used as synchrony metrics (again computed for each 1-sec epoch). Focus, mood, closeness, and personality questionnaires [9-11] were included in all studies.

Results/Discussion. Students' brain activity was more synchronized with their peers and teacher if they liked each other better, when they enjoyed a class activity better, and for those students who were more socially aware [2,3]. Students further showed higher synchrony and higher quiz scores for class content presented via videos than for lectures. Finally, students' occipital alpha power was consistently highest, and quiz scores were lowest, for early morning classes. Performance was best, and alpha power lowest, for mid-morning classes [4]. These findings provide evidence pertaining to the neural basis of classroom social dynamics and student engagement, two factors that have been found critical for student learning [12]. In addition, the alpha findings contribute brain data from real-world learning settings to the ongoing public debate about high school start times in relation to adolescent sleep patterns [13]. The role of engagement in brain-to-brain synchrony is further supported by the museum data [5]: those pairs of participants who reported more focus after than before participating, also exhibited an increase in brain-to-brain synchrony throughout the recording session. Additional factors that predicted synchrony include pairs' social closeness, empathy, and their self-reported strategy to increase connectedness. Taken together, we argue that our approach can generates rich datasets collected under ecologically natural circumstances, complementing and informing laboratory-based research on social engagement and learning.

***The following persons were co-authors on the work presented in the abstract**

Wan, L., Oostrik, M., Michalareas, G., Poeppel, D., Bevilacqua, D., Davidesco, I., Haegens, S., Kaggen, L., Van Bavel, J.J., McClintock, J., Chaloner, K., Rowland, J., Kahraman, H., West, T., Serafimaki, A., Struiksma, M.E., Ding, M.

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ID: 125 / **Poster: 8**
Poster Submissions
Topics: Mobile Brain/Body Imaging, EEG, Cognition and Motor Function
Keywords: motor learning, real-life skill, full-body movements, eye movements

Principles of motor learning in complex human skills

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Background. Motor skill learning is a key feature of our development and our daily lives, from a baby learning to roll, to an adult learning a new sport, or undergoing rehabilitation after a stroke. Human motor abilities are highly diverse, and as we keep learning new motor skills in all those skills we see tremendous diversity between individuals. While most of us can learn any skill, only some of us have the potential to excel in it. The process of real-world skill learning is long, complex, and difficult to quantify. As a result, it is rarely studied and very little is known about the behavioral and neural process of motor skill learning that makes some of us better learners. Such knowledge can change the way we teach kids, train athletes, or do rehabilitation.

Method. Here we use MoBI technology study real-world motor skill learning in a pool table billiard paradigm. We tracked the subjects full body movements with a 'suit' of inertial measurement units (IMUs), and their brain activity with EEG. Using this rich MoBI data, recorded while naïve subjects train in a novel task, we aim to unravel the key behavioral and neural processes that drive motor learning.

Results. Our results from the early phase of learning, while subjects are practicing repeated trials of the same shot, show for the directional error of the target ball (relative to the direction from its origin to the center of the target pocket) a classic double exponential learning curve with similar time constants to those reported in visuomotor and force field adaptation tasks. We farther show that the change in posture from trial to trial shows a classic singe exponential learning curve with a time constant of slow state adaptation, and the full body movement velocity profiles suggest an increase in the number of degrees of freedom over learning; as well as an increase followed by decrease in the overall variability, suggesting of exploration-exploitation trade-off. The results from an additional block towards a different pocket suggest generalization in the variability profile. The EEG activity over the left frontal cortex shows significant differences between successful and failed trials both in the fore period and post movement rebound. Additionally, we show a consistent decrease in the alpha desynchronization over trials which seems like a neural signature of the motor learning.

Discussion. We interduced a new paradigm for motor learning during full body movement in a real-world complex motor skill. The time constants of the initial adaptation curve in this novel paradigm are within the same range of those reported in the motor adaptation literature. This paradigm enables the study of the long and complex process of motor skill learning. The continuation of these learning curves and the generalization across different shots is not clear and the accumulating data of the following longitudinal experiment would give us insight to such principles of motor learning in complex human skill. The evaluation of changes in the complexity of behavior and its neural correlates would enable a systematic and integrative understanding of real-world motor skill learning and its neuronal requirements and constraints.

ID: 126 / Poster: 50
Poster Submissions
Topics: EEG, Cognition and Motor Function
Keywords: language, classifications, MoCap

Native speakers vs. linguists understanding of motion verbs

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Background. In the current poster, we compare existing linguistic classifications (e.g. Levin, 1993; FrameNet; Im Walde, 2006) of English, German and Greek motion verbs with clusters, which were based on MoCap and ERP. More precisely, (i) we recorded motion capture data (MoCap) from American, German and Greek native speakers, who performed the action that corresponds to the verbs of the linguistic classifications, in order to analyze them and find the patterns that coil the actions together, (ii) we recorded event related potentials to identify the neural representation of lexical knowledge of the same verbs –as in the existing linguistic classes. Previously, Hauk, Johnsrude and Pulvermueller (2004) demonstrated that the referential meaning of action verbs is related to somatotopic activation. We evaluated the same result with our verbs and motion captured clusters. (ii) we measured the structure of mental representation (SDA-M, Schack, 2014) to assess the action relevant organizational structures of the same verbs and actions, since participants were asked to find the relation between words (for verbs) and avatars (for actions).

Results. Even though linguists are based on subcategorization or other syntactic criteria, their classifications agree with the broader kinematic and neurological clusters. Probably, intuitively they rely on the nature of action and its somatotopic attributes. Concerning German native speakers, unlike linguists, they cluster verbs in the same way as actions. They seem uninterested in walking-like actions and they separate them only when a significant change of path occurs (e.g. change of the z axis, upwarddownward motion). Even in this case, they do not coil together similar manners (hochsteigen, runtersteigen), which is done in the kinematic cluster, but similar path (hochsteigen, hochgehen). Given the fact that English and German are manner languages, the structural analysis implies that in everyday use native speakers emphasize on the first compound.

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ID: 127 / Poster: 21
Poster Submissions
Topics: Mobile EEG, EEG, Neuroergonomics
Keywords: mobile EEG, gait detection, gait artifact, event-related potentials, walking

Hands on gait correction: identifying and correcting gait-artifacts in mobile low-density EEG

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Background. In neuroergonomics one of the main goals is to be able to infer human cognition in everyday situations within common environmental settings using neurophysiological measures. For a long time, measurement devices, especially the EEG, have been thought to be too susceptible to noise and motion artifacts for non-laboratory recordings. Especially human locomotion has been shown to induce large gait-artifacts in most EEG electrode positions which can have a strong impact on signal to noise ratio. Here we present a new data-driven approach for gait-artifact identification and reduction.

Methods. In a first exploratory experiment, data was collected from 15 subjects with a low-density 30 channel EEG-cap and a portable, mobile amplifier (LiveAmp, Brain Products, GER). Participants performed auditory 1-back, 2-back and oddball tasks while standing, walking forwards (1.2 m/s) and walking backwards (0.8 m/s) on a treadmill. To guarantee complete mobility of the setup, stimulus-presentation was accomplished with a Raspberry Pi 2 (Raspberry Pi Foundation, GB) stored in a backpack worn by the subject. Using the built-in accelerometers of the mobile EEG amplifier, the participant's step cycles were detected and used to generate gait-locked events. As the stimulus presentation proceeded, participants aligned their gait to the ongoing stimuli. This stimulus synchronous gait behavior made previous gait-artifact removal techniques via moving averages over neighboring trials difficult to use as useful paradigm variance could be affected as well due to gait- and task-event synchrony. So, after filtering the data between 0.1 and 8 Hz, EEG data within the step-cycles were timewarped to the participant's task-specific mean stride length. Followingly, a general mean gait ERP was calculated per channel and across all task conditions. Subsequently, this mean gait ERP was warped to the individual length of each stride and subtracted from the continuous EEG signal. By averaging the mean gait ERP across all task conditions, only gait-related signal proportions should be subtracted from the signal while leaving the task-related signal intact.

Results / Discussion. First results indicate that by just using accelerometric data a large proportion of steps can be identified reliably. Further, subtracting the mean gait artifact might be a suitable way to improve signal to noise ratio in mobile settings while maintaining task-related brain dynamics, even if movements and stimuli appear at the same time.

ID: 128 / **Poster: 26**
Poster Submissions
Topics: Analyses Tools, EEG, Sports- and Movement Sciences, Cognition and Motor Function
Keywords: driving, cluster analysis, ICA, EEG time-frequency analysis, movement preparation

Electroencephalographic correlates of braking and acceleration events during simulated car driving

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Background. Driving is a complex behavior involving interrelated motor and cognitive elements (Calhoun et al., 2002). Many of these elements, have been studied separately using experimental paradigms designed to probe discrete brain systems but without attempting to analyze the complex temporal dynamics of driving (Spiers and Maguire, 2007). Hence, a comprehensive and temporally resolved picture of the cognitive processes involved in driving is still lacking, yet its achievement would be the key to predict human motor intentions while driving, such as braking and steering actions. The aim of the present study was to evaluate the electroencephalographic features possibly discriminating braking from gas events in an unconstrained simulated driving.

Methods. We collected high-density EEG data from twenty participants while they were driving in a car simulator. The EEG was separated into independent components that were clustered across participants according to their scalp map topographies. For each component, time-frequency reactivity related to braking and acceleration events was determined through wavelet analysis, and the cortical generators were estimated through minimum norm source localisation.

Results. Comparisons of the time-frequency patterns of power and phase activations revealed that theta power synchronisation distinguishes braking from acceleration events 800 ms before the action and that phaselocked activity increases for braking 800 ms before foot movement in the theta frequency range. In addition, source reconstruction showed that the dorso-mesial part of the premotor cortex plays a key role in preparation for foot movement

Discussion. The present study identified EEG correlates that can distinguish between braking and acceleration events in a time window far preceding the onset of action. Specifically, an independent component associated with the fronto-central electrodes exhibited synchronisation of theta EEG rhythm around 800 ms before the onset of braking, which is statistically significant, when compared with acceleration action. The topographical reproducibility of this component across participants indicates that the same channels may be exploited in a larger population to discriminate between braking and acceleration actions without the need for high-density recordings or single-subject identification of independent components. The discriminatory power of this component is reinforced by ITC analysis, the results of which show an increase in phase coupling 800 ms before the onset of braking. These results extend the recent literature on driving research by showing evidence that it is possible to semi-ecologically distinguish, without external cues, the braking from the gas action by means of a theta synchronization 800 ms before the event. Such result provides a wider time window interval with respect to other action detection methods in driving (Haufe et al., 2014; Khaliliardali et al., 2015; Kim et al., 2015), with a larger possibility to build a driving assistance technology in a near future

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ID: 129 / Poster: 30
Poster Submissions
Topics: Analyses Tools, EEG, Synchronization, Cognition and Motor Function
Keywords: ethomics, eeg, motion capture, eye tracking, extreme driving

Neural Motor Behavior in Extreme Driving

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Background. Most studies on driver behavior [1-4] have focused on understanding and measuring their attention, fatigue, and drowsiness, and less so on evaluating the neurocognitive and neuromotor response while driving. Here we aim to address this gap, specifically, by focusing on expert driver performance (Formula championship level) under extreme driving conditions (high speed, low temperature, wet road), where the skill of the driver is optimally displayed. Determining neural motor behavioral patterns, when regaining control of the car after unexpected events, will allow us to develop of specific in-vehicle and in-body technologies able to prevent critical conditions and improve driving safety.

Method. A professional race driver, drove an Audi R8+ on the TopGear Race track, while equipped with: a 32-ch wirelessEEG system with dry electrodes (Brain products); an eye tracking glasses (SMI Eyetracking Glasses 120 Hz); IMU's on his hands and feet (Awinda); and an Apple Watch to monitor his heart rate. The car included a GPS system, and a cabin mounted camera recording the driver and the track. This test drive was pre-scheduled by the racing team, who race in these conditions frequently, for promotional purposes. It enabled us this unique scientific observation of motor expertise in the wild. The driver assistance system of the car was turned off at the driver's request. Timestamp synchronization was performed across all data streams. Sensor calibrations were verified outside the car and inside the car.

Results. The analysis of inertial data enabled to track both hand and foot movements with respect to the car position on the circuit track. Abrupt steering movements were identified as moments of loss of control of the car, verified by using the video from inside the car. The entire dataset was processed as follows: EEG was blindly cleaned; IMU's data were linearly regressed using information on the car movement and converted to absolute velocity. We quantified the strength of alpha band power and the length of eye fixation (a), as well as hand and feet absolute velocity (b) with respect to the position of the car on the race track. Correlation analysis showed the impact of each data component on the others, namely car gyroscopes (carG), accelerometers (carA), velocity (carV), the absolute velocity measure from all sensors (RightHand-RH, LeftHand-LH, RightFoot-RF, LeftFoot-LF), head acceleration (Head), the eye gaze fixations (Eye), and the brain band power (delta, theta, alpha, beta) in the motor cortex.

Discussion. We find a high degree of correlation between limb movements and car movement, as expected, but also quantified the correlation between alpha waves with respect to more extreme hand movements during steering. This data capture and analysis will enable us to attempt to obtain predictive markers of car drifts, and other reactions during extreme driving events.

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ID: 130 / **Poster: 40**
Poster Submissions
Topics: Mobile EEG, EEG, Neuroergonomics, Cognition and Motor Function
Keywords: EEG, passive BCI, neuroadaptive technology, cockpit, alert

Towards a Neuroadaptive Cockpit: First Results

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Background. Current-generation aircraft still rely on pilots to resolve critical situations caused, among others, by system malfunctions. It is therefore essential for safety that pilots immediately understand the severity of ight deck alerts, and do not miss alerts, e.g. due to high workload (Casner & Schooler, 2015). Failed, delayed, or otherwise inadequate response to alerts has been associated with several fatal accidents in the past (BEA, 2000; AAIASB, 2006; ASC 2016). Passive brain-computer interfaces (pBCI; Zander & Kothe, 2011) may be able to monitor the pilots' cognitive states and assess in real time whether or not an alert has been perceived. Furthermore, a pBCI system may be able to determine how the pilot interpreted a perceived alert, allowing the aircraft to adapt intelligently to the state of the pilot (Krol & Zander, 2017).

Methods. 28 aircrew aged 29{62 participated in a two-part experiment. Their electroencephalogram (EEG) was recorded throughout using a 32-channel mobile, wireless Brain Products LiveAmp system. First, a number of desktop-based experiments were conducted including an auditory oddball (Debener, Makeig, Delorme, & Engel, 2005). Participants performed 10 blocks during which a sequence of 60 auditory tones was presented. Each tone could be either a 'standard' tone occurring 70-80% of the time, a 'target' (10-15%), or 'deviant' (10-15%). Participants counted the target tones. Next, pilots were seated in a _xed-base ight simulator similar to current-generation business jets. During a 20-minute ight using instrument ight rules, they were presented with routine air traffic control messages, a fuel pump failure, four spurious alerts, and an engine _re warning. We calibrated a windowed-means classifier (Blankertz, Lemm, Treder, Haufe, & Mueller, 2011) on the EEG data recorded for each individual participant during the oddball paradigm to distinguish between their neurophysiological response to a standard tone (unimportant) and a target tone (important). We then applied this classifier to the data recorded during that same participant's flight, attempting to classify the above-mentioned events as either the comparable equivalent of \unimportant" or \important" based solely on the participants' EEG data less than one second after onset of each event.

Results. The classifier returned a number between 1 and 2, signifying that the neurophysiological response was closest to the activity following target (1) or standard (2) tones in the oddball paradigm, respectively. The value scales linearly between these numbers. Figure 1 shows the grand average across all alerts and all subjects of this output. Significant differences ($p < 0.05$), calculated using permutation tests with 100 000 permutations, are indicated using asterisks.

Discussion. Although not all events can be clearly separated from each other based on this data, the results do show that a classifier trained using an abstract attention task can produce significant differences between events recorded during a different, realistic scenario. This indicates that it is possible to calibrate a classifier in a brief, standardized fashion, and apply it in real-world contexts. It can then be used as a real-time monitor of the cognitive state of persons engaged in various tasks. Future neuroadaptive cockpits may

be able to detect when a pilot has perceived a warning and how it was interpreted, enabling it to interact with the pilot accordingly (Zander, Krol, Birbaumer, & Gramann, 2016; Krol, Andreessen, & Zander, 2018).

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ID: 131 / **Poster: 16**
Poster Submissions
Topics: Mobile Brain/Body Imaging, Analyses Tools, Sports- and Movement Sciences, Cognition and Motor Function, Gait- and Gait Rehabilitation
Keywords: Schizophrenia, Embodiment, Motion Capture, Surrogate Synchrony (SUSY)

Schizophrenia and the Moving Body: Motor Markers of Disembodiment

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(The following abstract presents the research design of a starting PhD project)

Background. We have diagnosed and treated schizophrenia for over a century but have not come very far in alleviating its burden [see e.g. 1]. This may be due to a simple, but essential aspect, widely ignored in conventional diagnostics, treatment and research: the moving body [2]. Evidently, there is no mental illness that does not affect the (moving) body and vice versa is affected by it. The recent *embodiment approach* focuses on the bidirectional interplay of body and mind and regards schizophrenia as a prereflective disturbance of the embodied self, a *disembodiment* [3-5]. This contrasts current neuropsychological theories, yet has not resulted in a fundamental change of research methods and diagnostics. Concerning patients with schizophrenia altered motor behavior has already been described as a symptom by Kraepelin and Bleuler in the 19th century [6, 7]. Genuine motor abnormalities (GMA) – as a primal symptom of the illness, independent of medical side effects – can be observed in over 50 % of affected individuals [8, 9]. The most frequently reported motor symptom is motor incoordination [10-12]. Although motor abnormalities are considered an important domain of schizophrenia pathophysiology and significantly contribute to the patients' self-alienation, they are not observed and indicated in the standard setting of clinical care [13]. Widely used assessment scales, such as the Positive and Negative Symptom Scale (PANSS) include motor symptoms in a very imprecise and highly subjective way [14]. Very few of the assessment tools examine full-body movement [15].

Methods. In order to explore movement characteristics of individuals with schizophrenia in an objective way, full-body motion capture (MoCap) is applied. Fourty participants (20 individuals with a diagnosis of schizophrenia, 20 healthy controls) are invited to the Heidelberg Center for Motion Research (HCMR). Participants are recorded while walking on a treadmill or doing coordination tasks (Tandem Walk). 8 MoCap cameras (Qualisys, space accuracy 1mm, temporal resolution 1 Hz) capture 48 markers attached to the participants' skin. Data is stored, assessed and further processed using Qualysis Track Manager and Visual3D. In a data-driven analysis, motion patterns of patients and controls will be explored using an algorithm defined by Troje and colleagues [16]. Furthermore, intrapersonal movement coordination will be quantified based on cross-correlations of movement time-series of participants' body parts. This will be calculated using another algorithm, SUSY (Surrogate Synchrony) [17].

Results. The project is expected to create an adequate experimental design to objectively study and diagnose the motor dimension of schizophrenia as well as to define motor markers of schizophrenic disembodiment.

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ID: 132 / Poster: 41
Poster Submissions
Topics: Mobile EEG, Mobile Brain/Body Imaging, EEG
Keywords: Mobile EEG, In-home, cognitive workload, daily-life activity

An afternoon of natural activities at home through the eyes of mobile EEG

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Background. With the emergence of mobile electroencephalography (EEG) understanding the physiological basis of cognition in real-world situations becomes possible (e.g. [1]). EEG indices of engagement, alertness and cognitive load have been extracted with explicit stimuli in specific (visual) tasks, e.g. [2,3].We would like to use those indices to shed light on natural real-life activities in which subjects feel completely at ease (cf. laboratory setting). We recorded mobile EEG data for 2,5 hours at home during which the subject performs a variety of real-life activities (e.g. Reading a book, playing a game). The purpose of this pilot experiment was to determine if the aforementioned EEG-based indices as described in the literature can provide meaningful insights to daily-life activities as obtained through truly mobile EEG recording over a longer time period.

Method. 2.5 hours of EEG on one subject was recorded in the living room and kitchen with a SMARTING mobile EEG amplifier from mBrainTrain (Belgrade, Serbia, www.mbraintrain.com). This amplifier was paired with a Sony Xperia XZ1 mobile phone for data recording of 24-channel EEG data. The subject was instructed to perform following activities for roughly 10 min in the order she preferred: 5x Rest (5 min), 2x Air traffic controller game, Wikipedia game, Read book, Mental Relax, Watching Netflix (20 min), Sudoku, Work on laptop (20 min), Listen to music and Household activities. Data were 0.5-40Hz band pass filtered and EOG artifacts removed through automated ICA. Spectral power densities of the following EEG bands were calculated for each 4-s epoch. Frequency bands were extracted as follows: theta (4 to 7.9 Hz), low-alpha (8 to 10.9 Hz), high-alpha (11 to 13.9 Hz), and beta (14 to 29.9 Hz). Five indices were calculated as reviewed by [2]: low-alpha and high-alpha averaged across all sites, Engagement Index (EI) which is the ratio of beta to (alpha+theta) for central-parietal sites Cz, P3, Pz, and P4; the frontal theta index (channel Fz); and Task Load Index (TLI), ratio of theta Fz to alpha at Pz. See 2. and references herein for a thorough description of these measures. Besides EEG we asked the subject to note the level of sleepiness, difficulty and enjoyment of each current activity.

Results. On average roughly 82% of the data was preserved after artifact removal. On the cleaned data, lowalpha, and to a lesser extent TLI, high-alpha and the frontal theta index distinguished between the rest and task related activities.. Ranking the activities based on the EEG indices revealed meaningful separation of easy tasks (i.e. Rest, Reading and Netflix) from more (cognitive) demanding tasks (i.e. Sudoku, Airtraffic controller game and Wikipedia game) for the TLI, low-alpha and Frontal theta indices. These results validate previously reported results in lab /carefully controlled environments in the real world [2]. Finally, the indices were averaged per activity and correlated with the user-ratings. The level of fatigue and low-alpha, TLI and Frontal theta were marginally significant. A trend towards increased likability, of the activity, and TLI and Frontal theta was observed as well.

Discussion. The preliminary results demonstrate the feasibility of recording mobile EEG during several natural activities in-home. Indices for tracking workload, fatigue and engagement provided meaningful estimates with respect to the activities performed in the real-life scenario of our pilot subject. These results will be verified in a larger study, bringing cognitive assessment of daily-life activities within reach.

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ID: 133 / Poster: 36
Poster Submissions
Topics: Mobile EEG, EEG, Neuroarchitecture, Cognition and Motor Function
Keywords: architecture, motor-related cortical potentials, affordances

Incentive architecture: Investigating spatial affordances in architecture using MoBI and VR

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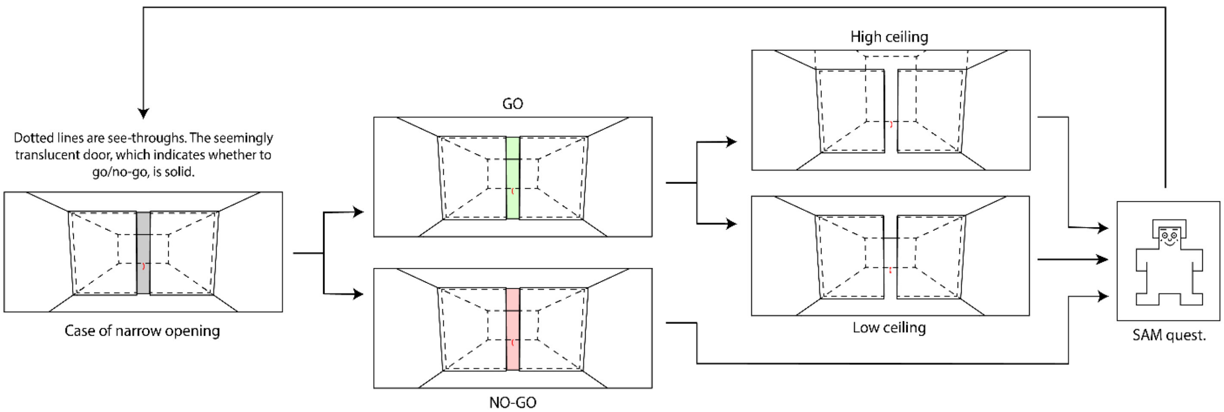
Background. Sequences of spaces are known to architects to have a certain impact on the perception and affective evaluation of spaces (1). Transitions themselves can be defined in time by the juncture between two spaces, and spatially as a delineating threshold between them, generally revealing a possibility for passing the threshold. Here, we investigated transitions using *openings* as delineating threshold, to gain a deeper understanding of the perceived affordance (2) of crossing the openings and how this impacts evaluation of the space. Transitioning from space to space includes coordinating the body according to certain spatial delineations, such as *openings*, and their configuration. We position this study as a link to the broader investigation of cognitive predictive mechanisms to better understand architectural transitions. The aim of this study is to investigate whether the physical passing, referring to affordances and active inference (3–5), co-vary with the motor-related cortical potentials (MRCPs), and whether these correlate with the emotional valence.

Method. Using a Mobile Brain/Body Imaging (MoBI) approach (6–8) we combined head-mounted virtual reality (VR) with mobile electroencephalogram (EEG), to investigate transition through different virtual openings. Participants were asked to transition between two spaces passing through openings of varying width and successive ceiling height. Participants were introduced openings that were too narrow to pass and openings that were difficult, but possible to pass, as well as easily passable (see figure). The task entailed an action-dependent transit (50% of trials), with the final goal to reach a red circle in the successive space. After each trial participants were asked to fill in the SAM-questionnaire.

Results. We hypothesized to find more positive MRCP activity in pre-frontal and parietal areas prior to action in spaces that provide higher affordances, compared to spaces that hinder the agent (9). Furthermore, we investigate whether the ceiling height of the successive space has an emotional influence, and whether the MRCPs may correlate with the introspective decisions.

Discussion. This study investigates the neural dynamics underlying action and cognition as predictive mechanisms revealing first insights into the affective influences of transitions on spatial perception of sequentially experienced spaces. Moving beyond stationary architectural investigations, such as pictures, transitions in VR provide an excellent point of departure for animate architectural investigations. Further, this investigation contributes to the architectural discourse of defining spatial threshold, suggesting the threshold of space goes beyond sole visual representation, and in turn also depend on sufficiently re-orchestrating the planned bodily trajectory. Transitions in architecture are non-stationary experiences, as most of architectural experience, and such animate insights of the impact of action-dependent transitions give rise to questioning fundamental architectural themes, such as open-spaces, corners, flow and homogeneity. Mobile EEG studies of architectural settings are crucial to better understand the bodily impact of a constantly growing built environment.

Figure



https://i.imgur.com/C6LpqFG.png

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ID: 134 / **Poster: 32**
Poster Submissions
Topics: Mobile EEG, Mobile Brain/Body Imaging, Analyses Tools, EEG, Synchronization, Cognition and Motor Function
Keywords: EEG, Virtual Reality, Mobile Brain Imaging, Dual Task Walking

Alterations of brain dynamics during natural dual-task walking

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Background. The neural basis of primary and secondary task performance during dual task natural walking has not yet been investigated systematically. Although recent studies have used treadmill setups with fixed visual displays1 or normal overground walking 2. while performing a secondary cognitive task, it is not well understood how the brain dynamics are altered with respect to both primary and secondary tasks. This speaks for the development of an experimental environment where the action space of an agent and any unwanted confounds that may impact brain dynamics of interest can be controlled. To this end, we developed and recorded brain dynamics of participants in a dual-task virtual walking scenario using a Mobile Brain Imaging (MoBI) approach3-5. To our knowledge, this is the first study to measure human brain dynamics during natural walking with VR stimulation. We argue that posture and movement have a considerable impact on a simultaneous cognitive task (cognitive motor interference) and its associated neural information processing.

Method. Electroencephalography (EEG) data (from N = 23 healthy young adults) was acquired using a 128-channels BrainAmp amplifier system wireless data transfer (BrainProducts MOVE). A virtual reality (VR) head mounted display (Acer Windows Mixed Reality) was used to present stimuli in a virtual environment designed via Unity (2017.3). All data streams were synchronized using the software Labstreaming Layer (LSL). Participants were instructed to either stand or naturally walk on an elliptic path while simultaneously performing a secondary visual discrimination task (Fig.1), that consisted in discriminating visually presented targets in the vicinity. The experiment comprised a 2x2x2x2 factorial design with repeated measures over ‘movement’ (standing vs. walking), ‘hemifield’ (left vs. right), ‘target’ (blue vs. yellow cube), and ‘eccentricity’ (15° vs. 35°).

Results. Results from a pilot study (N = 6) indicated a significant increase in response times in the walking condition reflecting dual task costs. Furthermore, after pre-processing the EEG data using EEGLAB v.1.3.4.4b and subsequent ICA clustering, two prominent Clusters were identified (in parietal and anterior cingulate cortex). The event related spectral perturbations (ERSP) were computed and compared between the movement conditions (Fig.2). The results suggest a modulation of theta power when transitioning from standing to walking in both regions of interest which will be further investigated in an ongoing study.

Discussion. We developed an experimental framework that enables a unique analysis of brain dynamics during natural walking with and without secondary tasks. Considering the main findings from the pilot study acquired from a small sample, we expect to find consistent effects in the movement condition in terms of performance and brain patterns based on a larger sample. In addition, the preliminary data pointed to several technical issues (e.g. field of view, stimulus type, hardware) that were addressed in the current study. In summary, this study aims at the development of an experimental tool that combines behavioural readouts, assessment of gait and secondary task parameters and the associated neural responses in mobile participants as a step towards real-world brain imaging.

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ID: 135 / **Poster: 49**
Poster Submissions
Topics: Mobile EEG, Mobile Brain/Body Imaging, Cognition and Motor Function
Keywords: Invisible Maze Task, Spatial Navigation, Active Exploration, Virtual Reality, Interactive Environments

Interactive Exploration of Sparse Virtual Environments: Mobile Brain/Body Imaging of directional change vs. no-change situations

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Background. The neuroscientific study of human navigation has been constrained by the prerequisite of traditional brain imaging studies that require participants to remain stationary. Such imaging approaches neglect a central component that characterizes navigation - the multisensory experience of self-movement. Navigation by active movement through space relies on idiothetic cues, i.e. information originating from navigators' movements as well as allothetic cues, i.e., information about objects and space unaffected by changes in body position and orientation. A well-established theory of spatial learning in children assumes an ontogenetic sequence from egocentric (body-centered) to allocentric (external world-centered) representations of space implying a sequential development from coarse to complex spatial representations1,2. We investigated the spatial micro genesis during repetetitions of free ambulatory exploration of interactive sparse virtual environments using motion capture synchronized to high resolution electroencephalographic (EEG) data as well psychometric and self-report measures. In such environments, map-like allocentric representations must be constructed out of transient, egocentric first-person perspective 3-D spatial information. Previously, we have shown changes in exploration behavior across repetitions of maze explorations, see figure 1. Here, we investigated directional change vs. no-change situations and their manifestations in exploration behavior as well as in brain dynamics of ROI clusters of independent EEG source signals.

Methods. Using a Mobile Brain/Body Imaging3,4 approach, we captured body motion of six rigid bodies and 157 channel EEG of 32 participants freely exploring an interactive sparse "Invisible Maze" environment by walking and probing for virtual visual wall feedbacks with their hand, delivered by a virtual reality (VR) headset. Participants explored four different mazes in three consecutive maze trials each. At the end of each maze trial, participants were asked to draw a sketch map of the maze from a bird's eye view perspective as an index of spatial learning. Two independent raters rated the usefulness of the sketch maps. A single model AMICA was used to separate multivariate EEG input signals into a set of statistically independent components (ICs)5. Subsequently, ICs were clustered using k-means algorithm with 10000 repetitions6. For each clustering solution we selected the cluster with the centroid located closest to the talairach coordinates of the retrosplenial complex (RSC). Ultimately, we ranked all clustering solutions by weighting each RSC cluster according to six criteria with the number of subjects per cluster weighing the most. Event-related spectral perturbations were then calculated for the highest ranking cluster solution epoched to each wall touch in change and no-change segments of the explored invisible mazes.

Results & Discussion. We observed event related perturbations in theta, alpha and beta frequency bands in the ROI cluster located in or near RSC. Contrasting directional change vs. no-change segments of the explored mazes is currently still under investigation. Furthermore, a network of six clusters was identified for further analyses elucidating the correlation between frequency band modulations and network interactions with (a) the efficiency of body motion through the mazes and (b) the resulting spatial representation indicated by the rated usefulness of the drawn sketchmap.

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ID: 136 / **Poster: 54**
Poster Submissions
Topics: EEG
Keywords: EEG, Virtual Reality, VR

Prototypical Design of a Solution to Combine Head-Mounted Virtual Reality and Electroencephalography

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Background. Research in neuroscientific imaging and neuroergonomics increasingly applies head-mounted virtual reality (VR) to display immersive and interactive stimulus environments. The combination of lightweight wearable sensors with functional infrared spectroscopy (fNIRS) or electroencephalography (EEG) offers new opportunities to study cortical correlates in stimulus rich and natural conditions. Emerging software developments in the field of VR also simplify the implementation of mobile and interactive experiments. Whereas most imaging techniques traditionally restrict participants movements in order to minimize artifacts, advanced technologies, such as Mobile Brain/Body Imaging1,2, open up new possibilities to investigate cortical activity and its relation with observable behavior in more natural and unrestricted settings. However, the use of VR goggles in experiments employing EEG measurements currently presents several challenges. When wearing VR googles in addition to the EEG electrode cap, straps and the VR goggles housing cause pressure on the electrodes leading to discomfort for users associated with headaches. In previous studies, factors such as weight, weight distribution of the headset and its physical ergonomics were mentioned as possible influences on simulator sickness3. The aim of this work is to improve the mechanics of both systems for the combined usage of head-mounted displays (HMDs) and EEG. The two main goals of this work were to provide a higher comfort for the participants as well as a simplified handling for experimenters.

Methods. After an initial phase deriving and weighing the core requirements by a group of experienced experimenters and lab personnel, we developed a protoype in an interactive development cycle utilizing principles from Agile and Lean Product Development. To test the usability of the prototype we conducted a study with four experimenters (two novice, two experienced) applying the prototype while thinking aloud and replying to a structured interview using items from the *systems usability scale* (SUS)4. Ultimately, to validate our developed prototype we tested 8 participants in a simple object selection task wearing two different HMDs. Here we tested the HTC VIVE and Acer Windows Mixed Reality Headsets. All participants completed two blocks wearing each, the original headset and the headset equippedwith our prototype. After each block participants were asked to complete a set of questionnaires, (1) the comfort rating scale5, (2) the simulator sickness questionnaire6 and (3) a set of additiona questions concerning the prototype.

Results & Discussion. We present our developed prototype and finnaly derived a set of questions suited for the “comfort” assessment of participants in experiments jointly employing head-mounted VR and mobile EEG.

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ID: 137 / **Poster: 27**
Poster Submissions
Topics: Mobile EEG, Mobile Brain/Body Imaging, EEG, Neuroergonomics
Keywords: EEG processing, engagement ratio, inattentional deafness, flight simulator

Pre-stimulus EEG engagement ratio predicts inattentional deafness to auditory alarms in realistic flight simulator

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Background. Accidents analyses and research conducted in simulated or real flight conditions indicated that inattentional deafness (ID) to auditory alarms could take place in the cockpit [1, 3]. Previous findings indicated that single trial event related potentials analyses over the electrophysiological signals could be used to detect ID [6]. However, a more relevant approach to improve flight safety would be to predict the occurrence of this phenomenon, thus paving the way to the design of \adaptive cockpit". To that end, a relevant approach is to measure shift in neural oscillations as a measure of attention [2]. In the present study, we propose to predict ID in a flight simulator by assessing the engagement ratio computed from pre-stimulus EEG signals. This ratio aggregates three main frequency bands (alpha, beta, theta) 5. and has been shown to be related to episodes of ID [4].

Method. An experiment was conducted with five pilots who had to perform a critical landing in a motion flight simulator. Along with the flying tasks, the volunteers had to press the sidestick trigger when they heard a rare auditory sound (\the alarm": 1250Hz, 80 sounds) interleaved with a frequent sound (1000Hz, 320 sounds) they had to ignore. A 32-electrode Biosemi ActiveTwo system was used to collect EEG signals recorded at 512 Hz. Continuous EEG signals were first re-referenced using two mastoid electrodes. Then, 1 second EEG epochs were extracted before onset of rare sounds. Epochs were split in two sets according to the pilot's behavioral responses: hit or miss. For each epoch and electrode, the following engagement ratio was computed: beta [13 30 Hz] / (alpha [8 12 Hz] plus theta [4 8 Hz]) according to [5]. This resulted in 32 measures per epoch, which were sent as features to a shrinkage linear discriminant analysis (sLDA) to discriminate hit versus miss epochs. Finally a 5-fold cross-validation procedure, with a balanced number of trials per class, assessed classification performances.

Results and Discussion. Our experiment revealed that inattentional deafness to single auditory alarm could take place as the pilots missed a mean number of 46.2 alarms. Our results disclosed classification performances higher than chance level (mean=0.62 std=0.027 –see figure 1, left) to predict the occurrence of ID using the EEG engagement ratio. Interestingly enough, the mean accuracy score to predict ID was higher for the engagement ratio that the mean accuracy score for each frequency separately (mean accuracy classification for alpha=0.53, theta=0.53, and beta=0.58). Consistently with previous findings [4], we observed higher ratio values before episodes of ID (see figure 2, right), especially in temporal areas. Taken together, these results indicate that the engagement ratio is a relevant feature to assess pilot's auditory performance and could be used for adaptive \alarm" (eg. dynamic modification of the alarm modality) and neurofeedback purposes.

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ID: 138 / Poster: 17
Poster Submissions
Topics: Mobile EEG, Analyses Tools, EEG, Therapeutic Intervention, Dance, Cognition and Motor Function
Keywords: dance therapy, network variability, EEG, chronic pain, depression

Neurorehabilitation associated with dance therapy for chronic pain and depression

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Background. There is a growing body of literature addressing the potential for dance to improve symptoms in neurodegenerative conditions (Bearss, McDonald, Bar & DeSouza 2017). Research in this area is challenging, however due to integrative, multimodal aspects of dance, which may include improvisational elements (Batson et al 2016; Olshansky et al 2014). Our group has developed methods to assess dance interventions by measuring changes in individual alpha peak power (iAPP) and correlating these with other measures related to quality of life, mental well-being, cognitive function, and motor behaviour (Barnstaple & DeSouza 2018). The current study looks at targeted dance interventions for chronic pain and depression.

Methods. This research has been conducted at multiple sites and is currently ongoing. Participants complete scales and a short questionnaire along with rsEEG scans pre and post the 50-minute dance sessions and at baseline/completion for iAPF and iAPP. rsEEG data are acquired using a wireless 14-channel Emotiv EPOC® EEG Neuroheadset and recorded with TestBench software (Emotiv Systems, 2012, San Francisco, CA). Electrode sites are in accordance with the International 10-20 System and include: AF3, F7, F3, FC5, T7, P7, O1, O2, P8, T8, FC6, F4, F8, and AF4, with two reference electrodes (CMS and DRL) at P3/4. The system samples at a rate of 128Hz with a 16-bit ADC resolution with digital notch filters at 50 and 60 Hz. All stimuli were created in and presented by MediaLab (v2012.4.119, Blair Jarvis for Empirisoft Co.,New York, NY). Data markers were sent from MediaLab to TestBench via Virtual Serial Port Driver (Version 7.1, Eltima Software, 2013, Bellevue, WA) (Levkov et al 2014; DiNota et al 2017).

Results. Data are analysed using the same data analysis pipeline previously implemented in our group's investigation of dance for people with Parkinson's disease (Levkov et al 2014; DiNoto et al 2017). A trend of overall increased alpha synchrony/power in the post-class condition has been detected in the chronic pain population, with a localised decrease in alpha power over SMA. In the mental health group, pre-class alpha power is seen to be notably lateralized towards the right hemisphere, and this lateralization is diminished post-class. Longitudinal results are currently being analysed.

Discussion. Chronic conditions such as pain or persistent depression affect a large segment of the global population and are often comorbid. There is growing understanding of the role of maladaptive plasticity these conditions (Liu et al 2017), and an emphasis on the role of brain networks (Kucyi & Davis 2017). Irregular activation and deactivation of the salience and default mode networks is associated with chronic pain (Kucyi & Davis 2015) and depression (Brakowski 2017). In the current study, alpha power reflects an average of all network activity, and the observed global strengthening and increased symmetry may reflect increased variability in network dynamics. Our next steps will be to look at the involvement of specific networks through further analysis and techniques such as fMRI and MoBI.

Literature

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ID: 139 / **Poster: 19**
Poster Submissions
Topics: Mobile EEG, EEG, Dance
Keywords: dance, mobile EEG, meditation, attention, performance

Dancing Attentional States: a mobile EEG case study of a dancer

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Background. In this case study mobile electroencephalography (EEG) data were used to investigate the attentional states of a dancer while dancing and imagining dancing. Neuroelectric studies of meditation demonstrate a link between an attentional/meditative state and increased power in the low alpha band (7.5 to 10.5 Hz) (Cahn & Polich, 2006; Fingelkurts & Fingelkurts, 2015). Studies of motor execution, motor imagery and movement perception using EEG demonstrate low alpha (7.5 to 10.5 Hz) as well as high alpha (10.5 to 13 Hz) and high beta (18 to 25 Hz) Event Related Desynchronisation in the central electrodes (C3, C4 and Cz) (Pfurtscheller et al., 2006) over motor cortex, and parietal electrodes (P3, P4 and Pz) (Orgs et al., 2008).

Methods. The dancer in this EEG case study was one of fourteen from whom heart rate and attentional state data were also collected. Fourteen expert dancers took part in an experiment during an advanced workshop with choreographer/dancer Rosalind Crisp. The baseline was a standing, eyes-open, resting-state. A *Do* condition was of a choreographic motor execution task from Crisp's practice which involved moving slowly. The *Imagine* or motor imagery condition was the same task, but imagined. One dancer also completed these same tasks at a different location on two consecutive days for EEG data collection. EEG data were collected using an ANT Neuro Eego Sports 64 Channel mobile EEG system. Power spectrum density analyses were undertaken after very noisy data was excluded. Heart rate was gathered using Empatica E4 wristbands and attentional state data using the Tammen scale (Tammen,1996).

Results. In the EEG experiment, high alpha and beta activity demonstrated Event Related Desynchronisation in the motor system as would be expected in a more controlled experiment. A significant increase in global low alpha in the *Imagine* condition over baseline was found as well as a significant decrease in global low alpha in the *Do* condition.

Discussion. These results could indicate an attentional state similar to meditation in the *Imagine* condition and movement activity in the *Do* condition. It is not clear whether there could have been an attentional state change in the *Do* condition as the baseline used did not include movement. This EEG case study was exploratory and the next step should be to replicate the experiment with more participants. In the expert group, heart rate significantly dropped between baseline and *Do* conditions and significantly more internal focus was reported in *Do* and *Imagine* conditions over baseline indicating that experiences across dancers may be similar and are worth investigating further using mobile technologies.

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ID: 140 / **Poster: 14**
Poster Submissions
Topics: Mobile EEG, Analyses Tools, EEG
Keywords: Wearable EEG, Cloud Analysis Tools, Large scale EEG, Low cost EEG

Low cost, high throughput sparse mobile EEG & ERP brain research with Muse

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Background. Muse, the world's bestselling EEG system by a wide margin, is a portable 4 (or 5) channel device now widely used in neuroscience research on ERPs, single trial classification, hemispheric asymmetry, VR, population dynamics, neurofeedback, numerous other paradigms, in clinical neurofeedback, and in neuroscience education at all levels. While some EEG and ERP researchers have questioned the utility of ultra-low-cost EEG systems in research, we demonstrate that Muse produces robust ERPs in classic paradigms, requiring 10-12 minutes per subject from setup to completion. We also show that remote, app-based longitudinal data collection with Muse generates useful, extremely large-scale population level EEG data, which may have broad utility in neuroscience and brain health research. We also show that other physiological signals such as electrocardiography (ECG), ballistocardiography (BCG) and respiration are robustly measurable with Muse, and describe how low-cost EEG and ERP based on Muse can be integrated into different wearable form factors, including sunglasses and VR/AR headsets.

Methods. We describe a suite of open source and inexpensive software tools that enable data collection and analysis with Muse, including mobile and desktop applications, cloud storage and file conversion, integration of Lab Streaming Layer, tools for ERP experimentation and analysis in python and iOS. We further describe a platform for scalable, unsupervised, longitudinal collection of remote EEG data from subjects at home or outside the lab, and describe its use neurofeedback or clinical mental health practice.The features and performance of the Muse ecosystem were tested in different scenarios using these tools.

Results.
Study 1. We assessed data quality and ease of use for remote EEG, via signal characteristics and session user experience metrics, on a small (1,118,000 sessions) subset of total individual user sessions, and describe how this unique data resource can inform new paradigms in neuroscience research.
Study 2. ERPs in an auditory and visual oddball task and a face/house paradigm are described, along with performance of single-trial classification using a Riemannian geometry based feature classifier pipeline.
Study 3. ECG (electrocardiogram) and BCG (ballistocardiogram) were recorded with Muse and are described herein, revealing a small mean absolute error in heart rate of 2.1 BPM, and suggesting that BCG measured on head provides a reliable estimate of some parameters of cardiac physiology.

Discussion. Beyond its use in classic sparse EEG/ERP data collection, Muse is sufficiently affordable and flexible that it may potentiate new ways of using electroencephalography inside and outside the lab. New mobile and web-based tools for Muse, including open source tools for neuroscience education, expand access and facilitate the introduction of EEG technology to novice experimenters and students.

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ID: 141 / **Poster: 3**
Poster Submissions
Topics: EEG, Cognition and Motor Function
Keywords: diagonal movements, upper limbs, EEG, alpha and beta, time-frequency

Oscillatory EEG modulation during arm movements across sagittal body midline

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Background. Diagonal arms movements has more intrinsic complexity compared to vertical movements because they involve the crossing of sagittal body midline and the active processing of left and right peripersonal hemispace. Diagonal movements have previously been used in rehabilitation protocols in order to promote cerebral plasticity and motricity [1]. Recently, Diamond supported the idea that diagonal movements and bimanual coordination could be effective also in cognitive rehabilitation [2]. Diagonal movements have been associated to specific changes in absolute beta and alpha power over fronto-parietal regions in a pre- and post- training study [3]. Yet, none of the studies which we are aware of examined this during actual diagonal movements. Therefore, we investigated the neural correlates of diagonal arm movements by recording cerebral electrophysiological activity during task performance, focusing our analysis on alpha and beta bands.

Method. 5 male volunteers performed 320 rhythmical movements (40 x 8 blocks) paced by an external sound while sitting on a chair. Movements were performed with both arms along two axes: Vertical (without midline crossing) and Diagonal (midline crossing at 500 ms) during which EEG was recorded. After pre-processing, we performed Indipendent Component Analysis in order to reject major motion artifacts. Finally, we extracted absolute power and computed time-frequency analysis. EEG signals were recorded using Eego sports amplifier and a 32 channels waveguard cap (ANT Neuro, Enschede, Netherlands).
Examples

Results. We found significant increase in beta power (14-30Hz) during Diagonal movements over Supplementary Motor Areas (SMAs) and Parietal Cortex (PC). Moreover, we have found significant greater beta power in left M1 and right Dorso-Lateral Prefrontal Cortex (DLPFC). Time-frequency analysis showed an interesting dissociation: in SMAs we observed greater lower alpha power (~9Hz) in Vertical movements slightly before 500 ms, and greater theta power (~6-7Hz) in Diagonal movements slightly after 500 ms. Moreover, we have found greater higher-alpha and lower-beta power (14-17Hz) over PC in Diagonal movements, respectively during the crossing and at the beginning of movement from crossed arms position.

Discussion. The increased beta power during Diagonal movements over DLPFC, M1, SMAs and PC seems to highlight the activity of networks that underlie attentional, sensorimotor and visuo-spatial processing. These results are in line with Moreira et al [1]. Time-frequency results showed that the execution of movements across body midline produces peculiar beta and alpha activity patterns over SMAs and PC. The pattern of theta/alpha activity during the arms crossing could give interesting insights on the functional role of Diagonal movements in motor and cognitive rehabilitation protocols. A similar theta/alpha modulation has been linked to encoding of new informations and increase in cognitive and memory performances [4]. Finally, massive integration of proprioceptive, sensorimotor and spatial informations could explain greater alpha and beta activity over PC during Diagonal movements.

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ID: 143 / **Poster: 37**
Poster Submissions
Topics: Gait- and Gait Rehabilitation
Keywords: EEG modulation, gait-phase, rehabilitation, stroke

Gait-phase related EEG modulations during gait rehabilitation after stroke – First results

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Background. A better interpretation of noninvasive electroencephalogram (EEG) brain oscillations after damage to the central nervous system (e.g. stroke) may lead to novel more effective and efficient motor rehabilitation approaches [1]. Recently, we proposed a model of cortical involvement during walking: Amplitude of mu (10-12 Hz) and beta (18-30 Hz) oscillations are suppressed (desynchronization) while high gamma amplitudes (60-80 Hz) are increased (synchronization) over central sensorimotor areas during walking compared to standing. Additionally low gamma (24-40 Hz) amplitudes are modulated related to the gait phase [2-4]. This normative model was developed in healthy persons. In this work, we present first results of the evaluation of the model in a stroke patient.

Methods. Based on our previously developed analysis pipeline, we applied high-density (63 channel, eegosport, ANT-Neuro, Netherlands) EEG source imaging based on individual anatomy and our new artifact correction method to enable neuroimaging during walking [3, 4]. Two hemiplegic patients that suffered an insult and participated in an in-patient rehabilitation protocol at the Klinik Judendorf-Strassengel participated in this preliminary study. We recorded magnetic resonance imaging (MRI) scans and EEG during walking at the beginning and at the end of the gait rehabilitation intervention. EEG was recorded while patients were actively walking in a robotic gait orthosis (Lokomat, Hocoma, Switzerland). The gait orthosis supported the patients in performing the movement of the impaired limb when necessary. Depending on the condition of the patient 10-15 minutes of EEG during gait were collected. Before and after 3-5 minutes of resting EEG were recorded (upright standing with eyes open). The experimental protocol was approved by the ethics committee of the Medical University Graz.

Results. In accordance with the results in healthy individuals [3, 4] a desynchronization of beta and synchronization of high gamma oscillations over sensorimotor foot areas during walking were observed in both patients. No mu activity was found. For one patient, upper beta/lower gamma amplitudes are modulated in accordance to the step pattern. The EEG sources of this gait-phase related modulation, however, show a distinct spatial pattern. Besides the sensomotoric foot area, we observed also activity in left sensorimotor areas as well as in right hemispheric parietal areas. Interestingly, the second patient's modulation pattern shows a modulation that is limited to half to gait cycle. However, a reduced modulation pattern would be very plausible in the case of hemiplegia after a stroke.

Discussion. The results are similar compared to the previous studies on healthy people [2, 3, 4], but not identical. The sample size of this preliminary study is however too low to provide reliable group results. Still, the results show that the measurement and analysis methods developed deliver plausible results in these two stroke patient case studies.

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ID: 144 / Poster: 28
Poster Submissions
Topics: Mobile EEG, Mobile Brain/Body Imaging, EEG, Cognition and Motor Function
Keywords: Bereitschaftspotential, readiness potential, electroencephalography, pre-movement brain activity

Assessing the Bereitschaftspotential before 192-meter extreme bungee jumping

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Background. Self-initiated voluntary acts, such as pressing a button, are preceded by a negative electrical brain potential, the Bereitschaftspotential (BP), that can be recorded over the human scalp using electroencephalography (EEG). Up to now, the BP required to initiate voluntary acts has only been recorded under well-controlled laboratory conditions but never in real-life environments. It is thus not known if this form of brain activity also underlies motor initiation in possible life-threatening decision making, such as jumping into a 192-meter abyss.

Methods. Two semi-professional cliff divers (both males, 19 years each) performed self-initiated voluntary jumps (jumper 1: n=15, jumper 2: n=12) outside the laboratory from a 192-meter bungee jumping platform (Europa Bridge, Innsbruck, Austria). For precise detection of self-initiated movements, a built-in acceleration sensor provided a clear trigger signal for reverse computation. EEG signal recorded from Cz was band-pass-filtered at 0.1-3 Hz, time locked to movement onset and then epoched into 3-second windows ranging from -2.5 to +0.5 s with a baseline correction relative to the first 0.5 s. Successful detection of a BP was defined as negative deflection of the EEG signal 400 ms before movement onset across all trials. The BP onset was defined as time point when the averaged EEG signal showed a continuous negative deflection for more than 500 ms.

Results. We report BP before self-initiated 192-meter extreme bungee jumping across both jumpers. Analysis of EEG recordings showed a clear negative deflection beginning approximately 1.5 s before movement onset. The maximum EEG deflection across all bungee jumps ranged at -17.62±1.09 μV.

Discussion. To the best of our knowledge, this is the first report on successful recordings of the BP outside the laboratory and in the context of self-initiating a voluntary act in possible life-threatening decision making. We found that the BP can be successfully detected by averaging EEG data from less than 15 trials documenting feasibility of such recordings outside the laboratory. Our results show that brain physiological assessments previously regarded unfeasible, e.g. assessment of the BP outside the laboratory and under extreme conditions, are now viable. Moreover, our findings pave the way to include pre-movement brain activity, e.g. the BP, into brain-machine interface (BMI) systems restoring activities of daily living to people with severe paralysis, e.g. stroke. The inclusion of such weak but very early brain signals indicating preparation of voluntary acts will help to advance BMI systems for applications in real-world environments.

ID: 145 / **Poster: 2**
Poster Submissions
Topics: Mobile Brain/Body Imaging, Analyses Tools, EEG, Synchronization, Neuroergonomics, Cognition and Motor Function
Keywords: virtual reality, immersion, vibro-tactile, error prediction, EEG

PREDICTION ERROR AS A MEASURE OF IMMERSION IN VIRTUAL WORLDS: COMPARING DIFFERENT SENSORY FEEDBACK CHANNELS

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Background. Virtual Reality (VR) applications promise an ever-growing potential as a medium for behavioral and cognitive research. In combination with neuroimaging modalities, VR can provide valuable insights into human brain activity in the context of cognitive and affective processing, rehabilitative, therapeutic or any other human-machine interaction. The primary challenge to make the VR experience more compelling, is to increase the sense of presence, i.e. the feeling of being present in a virtual environment. Here, we present an experimental framework to measure cognitive conflicts in virtual worlds as an indicator of presence. Conflicts are simulated as prediction mismatches arising from incongruent visual as well as vibrotactile feedbacks. The approach rests on the interpretation of human brains as prediction machines who match incoming sensory inputs with top-down expectations or predictions of the same [1]. We hypothesize that prediction error signals can be interpreted as indicators of immersion during dynamic interactions with virtual objects. We further assume that natural unconstrained interaction where users can move freely and interact with their surroundings in a natural way will amplify the prediction mismatches [2]. In a previous study [3], effects of different rendering styles of avatar hands were investigated during a simple 3D object selection task. Behavioral and brain-electric responses as measured with electroencephalographic (EEG) showed a sensitivity of the amplitude at approximately 50-250ms post object-selection movements. Furthermore, the negative prediction error potential correlated with the level of realism of the avatar hand, as uncanny valley theory suggests [4]. Taken together, these results show a correlation between the prediction error signal and the level of immersion.

Methods. We designed an experiment to explore the effects of different sensory feedback conditions on behavioral and brain dynamic responses. A simple 3D object selection task was used with targets presented equidistantly from the operator. In the first condition, cues related to object selection were indicated by a color change [3]. In the second condition, synchronized vibrotactile feedback was added to the visual stimulus. In both conditions, visual (or visual plus vibrotactile) feedback indicating object selection before the object was reached were presented in 25% of the trials (mismatch condition) to elicit a sensory mismatch. Participants selected objects in virtual reality using a head mounted display. A Leap Motion controller was attached to the head-mounted display to ensure a continuous tracking of participants' right hands during the experiment. Continuous motion capture data of the right hand was collected to mark the onsets of participants reaching movements. Continuous EEG data was recorded with 64 electrodes sampled with 500 Hz and filtered with a 0.016 high-pass and 250 low-pass filter referenced to FCz. Subjective measures of sense of presence and immersion (IPQ scale [5]) were collected for each condition.

Results & Discussion. We report a work in progress. The final results of the study are not available yet and we will present the results from ongoing analyses. We expect increased prediction error potentials for increasingly immersive stimulation, i.e. in the condition with visual and vibrotactile feedback as compared to only visual feedback. The EEG will be analyzed with a focus on the anterior prediction error negativity and analyses of the frequency domain to investigate differences between the stimulation conditions.

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ID: 146 / **Poster: 45**
Poster Submissions
Topics: Mobile Brain/Body Imaging, Analyses Tools, EEG, Synchronization
Keywords: EEG, dual-task design, aging, power spectral density, optic flow

Cognitive task engagement reduces the effects of sensory load on gait adaptation and electrocortical dynamics

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Background. While navigating complex environments the brain must continuously adapt to both external demands such as fluctuating sensory inputs, as well as internal demands, such as engagement in a cognitively demanding task. Previous studies have demonstrated changes in behavior and gait with increased sensory (Hollman, Brey, Robb, Bang, & Kaufman, 2006; McAndrew, Dingwell, & Wilken, 2010) and cognitive load (Yogev-Seligmann, Hausdorff, & Giladi, 2008), but the underlying cortical mechanisms remain unknown.

Methods. Here, in a Mobile Brain/Body Imaging (MoBI) approach sixteen young adults walked on a treadmill with high density EEG while 3D motion capture tracked kinematics of the head and feet. Visual load was manipulated with the presentation of optic flow with and without continuous mediolateral perturbations, and the effects of cognitive load were assessed by the performance of a Go/No-Go task on half of the blocks (De Sanctis, Butler, Malcolm, & Foxe, 2014).

Results. During increased sensory load, participants walked with shorter and wider strides, which may indicate a more cautious pattern of gait. Interestingly, cognitive task engagement attenuated these effects of sensory load on gait. Using an Independent Component Analysis and dipole-fitting approach (Gwin, Gramann, Makeig, & Ferris, 2011; Wagner et al., 2012), we found that cautious gait was accompanied by neurooscillatory modulations localized to frontal (supplementary motor area, anterior cingulate cortex) and parietal (inferior parietal lobule, precuneus) areas. Our results show suppression in alpha/mu (8-12Hz) and beta (13-30Hz) rhythms, suggesting enhanced activation of these regions during incongruent sensory inputs, associated with gait adaptation.

Discussion. We are currently collecting data on older adult participants who are often less able to adjust to ongoing cognitive and sensory demands while walking (Beurskens & Bock, 2012), to gain new insight into the neural underpinnings of mobility in aging.

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ID: 147 / **Poster: 42**
Poster Submissions
Topics: Mobile EEG, Mobile Brain/Body Imaging, Analyses Tools, EEG, Neuroergonomics
Keywords: EEG, MoBI, MATLAB, anaylsis, pipeline

The BeMoBIL Pipeline – Facilitating MoBI Data Analysis in MATLAB

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Background. Multimodal data analysis of high-density electroencephalography (EEG), motion capture (MoCap), and other data streams in Mobile Brain/Body Imaging setups (MoBI, see e.g. Gramann et al., 2011, Makeig et al., 2009) is a complex task. Therefore, establishing a comprehensive analysis pipeline, incorporating all steps from the raw data sets to plotting the final results, would strongly contribute to ensuring data quality and replicability.

Methods. For multimodal processing of EEG and MoCap data, MATLAB (Mathworks Inc., MA, USA) functions and scripts have been created, and several MoCap analysis functions were added in MoBILAB (Ojeda, Bigdely-Shamlo, & Makeig, 2014). Those include a new "rigidBody" data stream with the corresponding position and orientation, data processing, as well as effective motion onset and offset detection. EEG analysis functions are based on EEGLAB (Delorme & Makeig, 2004); in addition, comprehensive function wrapping, additional analysis options, and storage of all analysis parameters in the EEG data set struct were implemented. Furthermore, automatic data cleaning in the channel and time domain can be employed. Regarding clustering of independent components, additional functionalities for repeated k-means clustering and automatic selection of the most suitable clustering solution were implemented. Moreover, functions for the computation, visualization, and statistical analysis of single-trial ERSP data with time-warp information were created.

Results. The resulting MoBI data analysis pipeline comprises user-friendly, documented functions, as well as automatic documentation of all analysis steps. The functions can be downloaded at https://github.com/MariusKlug.

Discussion: The present data analysis pipeline aims at facilitating MoBI research by enabling researchers to focus on fast, efficient data analysis while maintaining qualitative, trackable, and comprehensive analysis documentation. The current state can be considered a beta version, and it is open to critique and contributions from the research community.

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ID: 148 / **Poster: 52**
Poster Submissions
Topics: Mobile EEG, Mobile Brain/Body Imaging, EEG, Neuroergonomics
Keywords: Situation Awareness, Neuroergonomics, Workload, EEG

Neural Markers of Situation Awareness in Mobile Virtual Reality

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Background. Situation Awareness (SA) is a construct defined as the perception, comprehension, and projection of elements in the environment (Endsley, 1995). While SA has been investigated behaviorally in various studies, the neural markers underlying the three levels are mostly hidden. Few studies have investigated SA using electroencephalography (EEG), employing limited methodological and analysis approaches in very specific stationary setups (e.g. Catherwood et al., 2014, and Berka et al., 2006).

Methods: We created a Mobile Brain/Body Imaging (see e.g. Gramann et al., 2011, Makeig et al., 2009) experimental paradigm using a virtual reality environment with dynamic reaction to target and distractor spheres moving towards the subject in order to investigate SA with varying difficulty settings. Data streams include high-density EEG, motion capture, and eye tracking, and thus allow for fixation-, movement-, and response-based analysis of event-related potentials and event-related spectral perturbations of source-localized EEG data, as well as investigations of mental workload and performance in the different tasks.
Results. Preliminary EEG and behavioral data will be presented.

Discussion. The created framework enables the investigation of SA using mobile brain/body imaging methods to shed light on its neural markers while dynamically and actively interacting with our environment. This will also allow for examining mental workload in more natural tasks than traditional seated experiments.

Support*:* Supported by the European Office of Aerospace Research and Development Grant ONR 10024807 to K.G.

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ID: 149 / **Poster: 31**
Poster Submissions
Topics: Mobile Brain/Body Imaging, Analyses Tools, EEG, Cognition and Motor Function
Keywords: Wearable technology, biomedical measurement, affective computing

Towards Gut-Brain Computer Interfacing: Gastric Myoelectric Activity as an Index of Subcortical Phenomena

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Background. Ambulatory, non-invasive imaging of insular phenomena has traditionally proven difficult with the limited spatial resolution of the most popular mobile brain imaging methods, electroencephalography (EEG) and functional near-infrared spectroscopy (fNIRS), which primarily acquire signals originating in the cerebral cortex. However, simultaneous fMRI and gastric myoelectric recordings on the abdominal surface have demonstrated an association between anterior insular activity and electrogastrography (EGG) [1], an noninvasive index of gastric slow waves produced by the interstitial cells of Cajal. The anterior insula is associated with cognitive and affective functions; the gut-brain axis (GBA) has been shown to influence affect, motivation, and decision-making [2]. There lies potential using changes in gastrointestinal activity as an index of insula activity.

Method. Participants (N=33, ages 20 to 59, mean age 27.43, 16 males, 17 females) with no known gastrointestinal, neurological, or psychiatric disorders were presented emotionally salient film clips (3 positive labeled “amusement”, “happiness” and love”, 3 negative labeled “sadness”, “disgust”, and “fear”) with standardized cinematographic styles from [3]. At the end of each movie clip, participants answered a self-assessment of their valence, arousal, dominance, liking and familiarity, modeled after [4]. To record EGG signals, we used the medical gastroenterology setup described in 5. and disposable Ag-AgCl electrodes (Skintact, F-301 gel electrode) connected to an EEG amplifier sampled at 256 Hz. Figure 1 illustrates the full electrode montage.

Results. Controlling for the “dominance” measure, EGG signal analysis in the frequency domain demonstrated statistically significant changes from negative movie segments ($p = 0.0209$, linear mixed effects model). Positive movie segments did not produce statistically significant changes ($p = 0.4706$). Figure 2 shows a comparison of normal EGG signals (0.05Hz, left) and signal during movie stimulus (right).

Discussion. Our preliminary results support previous work that gastric myoelectric activity can potentially be used as an index of affective processing occurring in the anterior insula [6]. In line with previous work, the “sad” movie clip produced the greatest significant change [7]. We hypothesize that our positive movie clips were ineffective at eliciting the target affective state; the dominance ratings for positive movie clips were significantly higher than for negative movie clips ($p = 0.003$, student’s t-test) with a mean score that suggests a high level of control in emotional response (Dominance = 3.613). We anticipate that continued spatial and time-domain analysis of the full electrode montage for additional research questions will yield additional results.

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ID: 150 / **Poster: 39**
Poster Submissions
Topics: Mobile EEG, Mobile Brain/Body Imaging, Cognition and Motor Function
Keywords: Alzheimer's Disease, Cognitive-motor interference

Mobile Brain/Body Imaging (MoBI) Assessments of Cognitive-Motor Interference in Alzheimer's Disease

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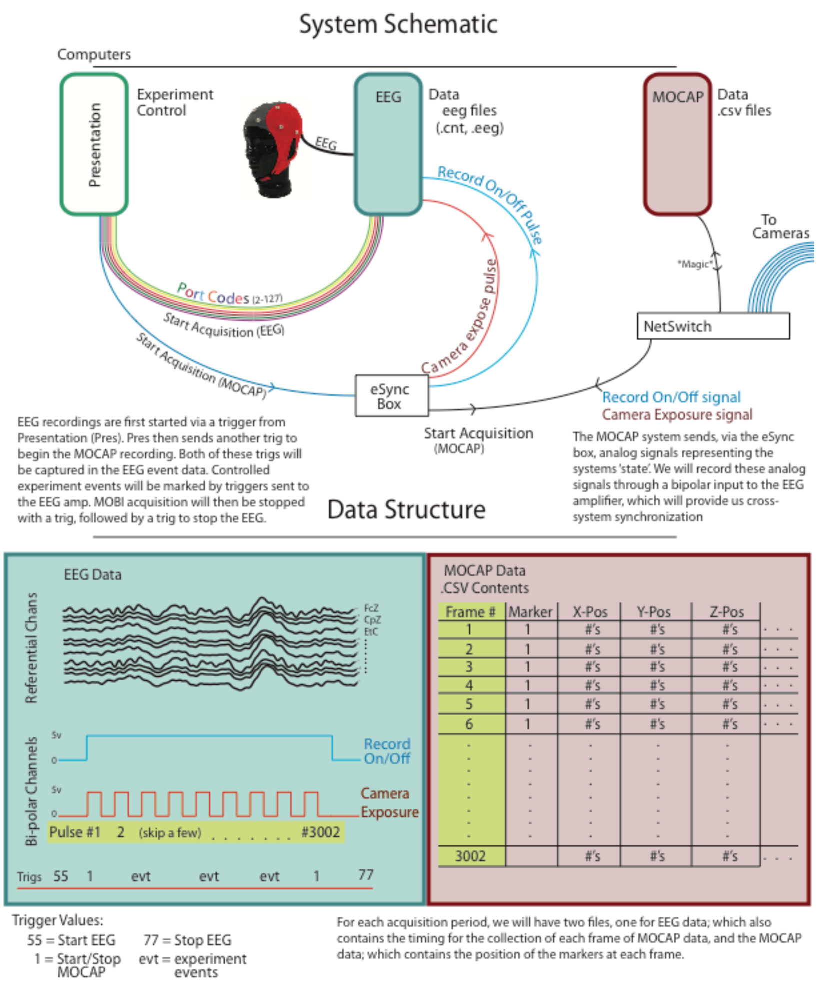
Background. A growing body of evidence demonstrates that attentional shifts towards cognitively demanding tasks can interfere with the execution of physical tasks (and vice versa). This cognitive-motor interference (CMI) can be clearly exposed through analysis of gait metrics.[1,2] This notion of cognitive load dominating allocable cortical resources is of particular importance to several patient populations, including individuals with cognitive deficits ranging from temporary to permanent, and individuals predisposed to falling. Patients with Alzheimer's Disease (AD) or its precursor, amnestic Mild Cognitive Impairment (aMCI), display both of these characteristics. Our study aims to explore what limits an individual's ability to adapt to a discrete cognitive load, improve upon existing capabilities for assessing fall risk, and explore novel methods for early identification of AD and aMCI.

Methods. We will employ Mobile Brain/Body Imaging (MoBI), combining EEG with high resolution motion capture software to relate the brain's electrophysiological events to kinematic data. An auditory oddball paradigm will be used to evoke auditory mismatch negativity in subjects. Control subjects, subjects with aMCI, and subjects with AD will be presented with standard (100 ms duration) and deviant (180 ms duration) auditory tones at fixed and variable interstimulus intervals while sitting, standing, and walking on a treadmill. Motion capture recordings of the subjects' gaits will be collected using 16 Optitrack Prime 41 cameras. Electroencephalography synchronized with the motion capture recording will be simultaneously collected using a mobile ANT Neuro EEG system.

Results. The first phase of this study will be performed between April 2018 and June 2018, with the ensuing results to be discussed at the 2018 Mobile Brain/Body Imaging Conference in July 2018.

Discussion. Previous studies out of the Cognitive Neurophysiology Lab of Dr. John Foxe at the Albert Einstein College of Medicine utilized MoBI to demonstrate age-related differences in cognitive task performance and event-related potential modulations during dual-task loads, suggesting a constrained neurophysiological flexibility in aging populations.[3] We intend to build upon the results of these studies and begin to develop a neural 'stress test' capable of exposing vulnerabilities within the electrophysiological, cognitive, and motor domains (similar to how a cardiac stress test might reveal any cardiovascular susceptibilities). Using the results of these experiments, we will attempt to define the factors that contribute to cognitive-motor interference and exacerbate the risk of falling. Furthermore, given the ability of MoBI to simultaneously assess perturbations in electrophysiological, cognitive, and physical domains, we will strive to uncover novel biomarkers indicative of aMCI and AD.



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ID: 151 / **Poster: 43**
Poster Submissions
Topics: Cognition and Motor Function
Keywords: reference frame, spatial cognition, mouse tracking

Empirical evidence on the choice of spatial reference frame depending on language and complexity of perceived relation

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Background. Spatial relations in English, German, Italian and Polish can be interpreted regarding three reference frames: absolute, relative, or intrinsic, depending on the situation. In everyday situations, native speakers of these languages use either the relative reference frame, which includes three strategies (facing, rotation, align) or the intrinsic one (Levinson 2003, Tenbrink 2011). The aim of the poster is to show whether native speakers of the selected languages interpret dimensional spatial expressions of the first (`in front of', `behind') and second horizontal axis (`to the right / left of') with respect to the same reference frames in various simple static and dynamic situations. Furthermore, it is investigated, whether participants change their perspective interpreting complex spatial relations – supplemented by artificial agent. In particular, we are interested whether participants interpret these complex situations from their own perspective or from the artificial agent's point of view.

Method. We conducted questionnaire and mouse tracking study. The questionnaire is considered as basis for mouse tracking, which was implemented to examine the decision behavior in detail. Within we examined the interpretation of 248 sentences and illustrations of static spatial relations. In the simple condition, participants interpreted the location of a bottle in a room with different furniture, answering a question. In the complex condition, an agent was additionally introduced and participants completed sentences like "Hans says that the bottle stands…" which differed in the semantic of embedding verb.

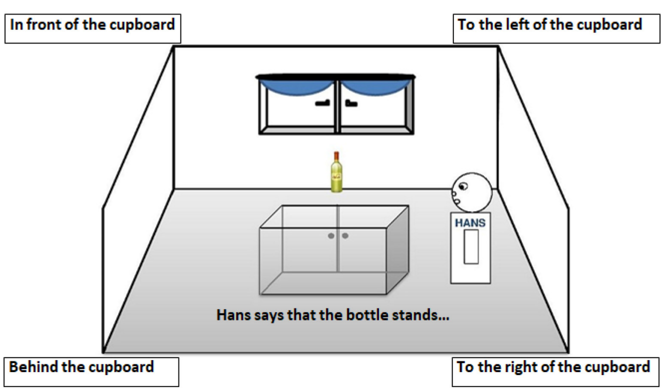

Figure 1: Selected intrinsic spatial situation from the mouse tracking experiment

Results. The results of the questionnaires with 561 participants show significant differences in the interpretation of `in front of' and `behind' between German and English speakers in extrinsic dynamical simple relations. Italian native speakers deviate most frequently from the egocentric assignment of the sides, specifically in the interpretation of `to the right / left of' a cupboard.

ID: 152 / **Poster: 6**
Poster Submissions
Topics: Mobile EEG, Mobile Brain/Body Imaging, Cognition and Motor Function, Gait- and Gait Rehabilitation
Keywords: Error related potentials, gait adaptation, executive functions, EEG, ICS

Error-related brain dynamics predict step adaptation in a challenging gait task

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Background. Gait is not merely automated motor activity but requires attention and other executive function (EF). Relationships between age- and disease-associated declines in cognitive function and mobility are of increasing interest. A growing body of evidence using dual-task walking paradigms indicates a pivotal role of EF in gait control and fall prevention in the elderly and Parkinson's subjects (Mirelman et al, 2012). EF may compensate for age associated decline in motor function, however evidence suggests that EF itself is involved in challenging gait tasks (Potocanac et al, 2014). In a recent gait study using EEG imaging (Wagner et al, 2016), we provided direct proof of involvement of EF and prefrontal control in gait adaptation.

Method: To further pinpoint the roles of cognitive control processes in gait adjustments we examined the source-resolved EEG dynamics of participants attempting to step in time to an auditory tone sequence. Participants had to adapt their step length and rate to shifts in tempo of the pacing stimulus (e.g., following unpredictable shifts to a faster or slower pacing tempo).

Results. Analysis revealed a negative potential in the source-resolved EEG, localized to dorsomedial prefrontal cortex (DMPFC) 200-300 ms after onset of the tempo-shift marking stimulus (Figure 1). Multiple regression analysis shows that single-trial amplitude of this negative deflection predicts the size of the subsequent step adaptation for tempo readjustment (R2 = 0.2) beginning 500 ms after the shift-marking cue.

Discussion. Negative scalp event-related potential peaks over DMPFC ~250 ms after incorrect button presses, described as error-related potentials, have been associated to control functions including error correction (Holroyd & Coles, 2002). Our results suggest that error correction processes are directly involved in gait adaptation allowing flexible adaptation of steps to changing external requirements. Future research will investigate age- and disease associated impairments of these control processes in gait disorders to develop biomarkers for fall risk prediction, e.g. in early-stage Parkinson's

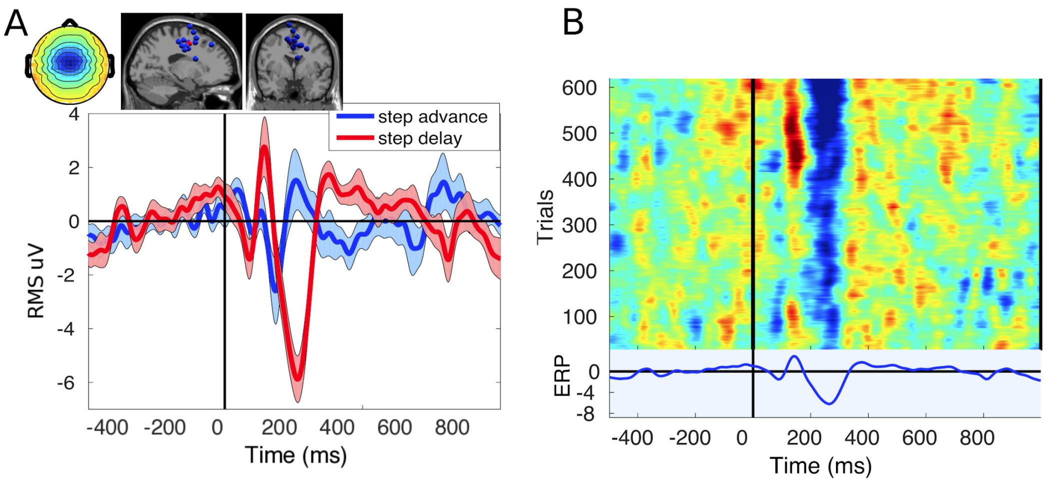

Figure 1: A) Cluster mean scalp projection and cluster single equivalent current dipoles and average ERPs relative to the tone cueing step advance and step delay perturbation. B) Single trials of all 14 subjects for step delay perturbations sorted by the normalized size of the adptation step. A larger negative amplitude in the EEG potential predicts a larger adaptation step producing a better adptation to the new tempo (adptation step is defined as inter-step interval (ISI) between 2nd and 3rd steps following the tempo shift expressed as percentage change in pre-shift ISI)

Support*:* Supported by U.S. NIH grant 5R01NS047293-12 and by a gift to UCSD from The Swartz Foundation (Sag Harbor NY).

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ID: 153 / **Poster: 10**
Poster Submissions
Topics: Mobile EEG, Mobile Brain/Body Imaging, EEG, Cognition and Motor Function
Keywords: EEG, mobile, oscillations, movement, rotation

Human retrosplenial activity during physical and virtual heading changes revealed by mobile brain-body imaging (MoBI)

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Background. The retrosplenial complex (RSC) is indispensable for spatial orientation, utilizing vestibular and proprioceptive sensory information to efficiently update spatial representations of heading during active body rotation. However, neural dynamics realizing physical body rotations and heading changes are poorly understood, since movement-related artifacts heavily confound electrophysiological recordings of brain data. Therefore, traditional brain imaging studies required the participants to lie or sit still in stationary desktop setups, which consequently must result in a limited understanding of how the human brain realizes whole body movements. In contrast, the present study overcomes previous limitations by investigating contributions of the RSC to spatial orientation in actively moving participants.

Methods. Mobile Brain-Body Imaging (MoBI; Makeig et al., 2009; Gramann et al., 2011, 2014) was utilized for the simultaneous assessment of high-density wireless electroencephalography (EEG) and motion capture of head movements. Nineteen participants performed a spatial orientation task, which required physical rotations of the whole body following a moving sphere in 3D virtual reality (head-mounted display). The same task was also performed stationary, i.e., by joystick control (2D standard display) without body rotation. EEG data were decomposed by independent component analysis; component clusters were assessed via repeated k-means clustering, and event-related spectral perturbations were compared between both rotation conditions in the most pronounced clusters of brain components (RSC and parietal regions; including ≥ 75 % of the participants).

Results. As expected, increasing rotation eccentricity was associated with less accurate heading estimations in both rotation conditions. However, during active physical rotations participants were more accurate in estimating heading orientation than in the stationary condition (visual flow only). Notably, neural activity in the RSC during active physical rotations showed prominent broad-band synchronization in 4-20 Hz frequency ranges. In contrast, visual flow only was associated with pronounced theta synchronization (4-7 Hz) in the initial rotation phase and with stronger succeeding desynchronization in alpha and beta frequency ranges (8-30 Hz), replicating results from previous desktop-spatial navigation studies (e.g., Gramann et al., 2010; Lin et al., 2014). Furthermore, neural activity in parietal regions demonstrated prominent alpha and beta synchronization during physical rotations, compared to the stronger desynchronization during changing visual flow only in the stationary setup.

Discussion. The present study allowed extracting neural correlates of spatial orientation in fully mobile participants, overcoming limitations of previous brain imaging studies. Our results suggest the pronounced involvement of the RSC and parietal regions during heading changes, as demonstrated by differential modulation of theta, alpha, and beta oscillations during active body rotation. Furthermore, revealing neural implementation of spatial orientation contributes to understanding the relevance of congruent vestibular and proprioceptive information for heading computations in healthy, and possibly clinical, populations.

Support: Supported by the German Research Foundation (DFG) grant GR2627/8-1 to K.G..

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ID: 155 / **Poster: 38**
Poster Submissions
Topics: Analyses Tools, EEG, Cognition and Motor Function
Keywords: signal processing, trial-reproducibility maximization, mismatch negativity, SSVEP

Two extensions of trial reproducibility maximization for EEG data analysis

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Background. Reproducibility of experimental results lies at the heart of scientific disciplines. However, EEG signals are notoriously noisy, and single-trial responses fluctuate considerably from trial to trial. Therefore, a signal processing method for reproducibility maximization is desired, especially in the field of MoBI where EEG signals are expected to be noisier than those in a laboratory setting. A standard method for a reliable response is to compute an average over many trials, as pioneered by Dawson (1954). Trial average enhances the reproducibility of a univariate time course such as single-channel data and an independent component. Intriguingly, there are only few multivariate methods that enhance the reproducibility of EEG signals.

Methods. We here propose two extensions of a trial-reproducibility maximization (TRM) method that extracts reproducible components on a trial-by-trial basis by taking a linear sum of multivariate time courses. Linear weights of EEG channels are determined so as to maximize the trial-by-trial reproducibility, as formulated as a generalized eigenvalue problem we published previously (Tanaka et al., 2013, 2014). A first method is to optimize not only a spatial filter but also temporal offsets of trials so that both evoked responses (time- and phase-locked) and induced responses (time-locked but not phase-locked) are analyzed in a unified manner. A second method is to maximize not only inter-trial reproducibility within a single subject but also inter-subject reproducibility across a group of subjects.

Results. This first method was applied to mismatch negativity (MMN) data and enhanced the reproducibility of event-related-potential wave forms with a valid scalp topography by compensating temporal jitters on a trial-by-trial basis. Moreover, the difference between the MMN components of deviant and standard conditions significantly. Then, the second method was applied to EEG data recorded from 35 subjects during a steady-state visual-evoked-potential (SSVEP) experiment and extracted group-reproducible components whose spectra matched with those of stimulus frequencies. Moreover, the extracted components were located in the occipital lobe consistently across all the subjects.

Discussion. We believe that the proposed extensions of TRM helps not only a better understanding of cognitive processes using EEG but also development of practical applications such as brain-computer interfaces, where trial-by-trial reproducible components are in need. Also, the proposed methods should reduce the number of trials necessary for a reproducible component, thereby extending the applicability of EEG to a real-world situation.

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ID: 156 / **Poster: 12**
Poster Submissions
Topics: Mobile EEG, EEG, Neuroergonomics, Gait- and Gait Rehabilitation
Keywords: EEG, cognitive-motor interaction, gait, machine learning

Classification of cognitive-motor interactions during walking via neural signals

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Background. Research suggests cognitive and locomotor brain networks overlap, and performing both task-types simultaneously can affect performance under some circumstances [1,2]. In this study, we submitted neural data to EEGNet, a deep learning network, to classify whether subjects were just walking versus simultaneously walking and performing a cognitive task via [3]. The ability to detect cognitive workload changes during physical activities is an important step towards monitoring cognitive state for adaptive human-agent interfaces.

Methods. All participants provided written informed consent in accordance with procedures approved by the Institutional Review Board of the US Army Research Laboratory. Subjects (N=18) walked on a treadmill with a rucksack either unloaded or loaded with 40% body weight for 1 hour while performing a visual oddball task during the beginning and end of walking. We recorded ground reaction forces and 256 channels of electroencephalography (EEG). For the oddball task, we presented stimuli in the center of a screen placed at eye level in front of the treadmill for 150 ms followed by a jittered 1500–2000 ms inter-stimulus interval during which only a fixation cross was displayed. Subjects were asked to fixate on the same screen when walking only, without the oddball task. We pre-processed EEG data by removing bad channels, filtering, and applying independent component analyses. We back projected independent components (ICs) identified as being cortically relevant to the channels. We epoched the data based on the gait event right heel strike (300ms before to 925ms after) and labelled as either just walking or walking plus oddball task. We combined data from all 18 subjects into one pool and randomly sampled out training, validation, and test data. We then applied EEG net, a compact convolutional network, to classify the data as either just walking or walking while performing the oddball task [3].

Results. EEGNet was able to quickly reach a classification accuracy of 92% of the EEG test data. This suggests that we may be able to detect changes in cognitive workload while participants walk with a heavy rucksack load.

Conclusions. This work is a step towards cognitive state classification during real-world tasks and suggests that EEGNet is a good method for classifying gait-related cortical signals. While we took caution to minimize EEG artifact differences between conditions, we are currently performing additional analyses to determine the extent to which artifact could have affected these results.

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Performance of conformable, dry EEG sensors

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Background. In recent years solid state "dry" EEG electrodes have become very popular as an alternative to the traditional wet electrodes to enable long term and real world monitoring of neural signals due to their ease of setup and use. To date dry EEG electrodes have been made from materials such as conductive fabrics, polymers, and metals [1,2]. Many of these electrodes adopt a vertical pin/prong style form factor so that they can penetrate hair and make the required skin contact. While this form factor works for some applications, they can become uncomfortable over relatively short periods of time. In many real-world scenarios, such as monitoring military personnel, these vertical prong style electrodes are also a safety hazard. As a solution to these problems, we have developed electrodes based on a polydimethylsiloxane embedded with carbon-nanofiber cross-linked filament (CNF-PDMS) to promote electrical conduction throughout a soft, pliable medium 3. while still allowing consistent performance across a range of compression [4]. Here, to ensure efficacy on scalp tissue, we describe human testing comparing the performance of CNFPDMS electrodes relative to commercially available, conventional wet and dry EEG electrodes for use during standard laboratory tasks. Additionally, we discuss the continuing challenge of community consensus on the proper quantitative assessment of "signal quality", rather than simple qualitative assessment, and propose specific approaches to solve this issue.

Methods. Eleven healthy adults participated in the initial study. This work has been reviewed by the U.S. Army Research Laboratory Human Research Protection Program under project #-ARL 17-084. We measured signals using three types of electrodes: dry (g.SAHARA (g.tec)), conventional wet (HydroDot, HydroDot Inc), and CNF-PDMS prototypes. Participants completed a three stimuli, rapid serial visual presentation (RSVP) task and eyes-open and eyes-closed baselines. All tasks were completed with the participants seated at a computer located in an electrically shielded, sound attenuated chamber. To assess signal quality, we computed typical event related potential (ERP) measures, as well as previously proposed (RMSE) 5. and new (correlation-based) benchmarking metrics for novel EEG technologies.

Results. We found that the CNF-PDMS electrodes demonstrated the expected ERP waves and changes in alpha power for the RSVP and eyes open/eyes closed baseline tasks respectively. Each electrode type measured significantly greater amplitude for the target stimulus than the standard background stimulus between 350-600 ms post-stimulus; g.SARHARA electrode ($p=0.014$, $t=2.72$); CNF-PDMS electrode ($p=0.018$, $t=2.58$), and Hydrodot electrode ($p=0.004$, $t=3.71$). The overall correlation between our CNFPDMS and HydroDot electrode was fairly high when looking across the entire time range measured; in fact, this was significantly better than observed between the g.SAHARA dry and HydroDot ($t(11) = 3.01$, $p=0.013$).

Conclusions. For the given tasks, the results using our quantitative approach showed that our dry, CNFPDMS electrode was able to demonstrate the expected neural phenomena and were more correlated to the conventional wet electrode than the g.SAHARA. This suggests that EEG electrodes made from CNFPDMS are suitable for recording EEG during standard laboratory tasks and perform similar to commercially available conventional wet and dry electrodes.

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